Exploring Traceability Challenges amongst Small Businesses in Tasmanian Red Meat Supply Chains: The role and potential impact of information technology

by

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I STATEMENT OF ORIGINALITY

This thesis contains no material which has been accepted for a degree or diploma by the University or any other institution, except by way of background information and duly acknowledged in the thesis, and to the best of my knowledge and belief no material previously published or written by another person except where due acknowledgement is made in the text of the thesis, nor does the thesis contain any material that infringes copyright.

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IV ABSTRACT

This study explores traceability challenges facing Tasmanian small businesses in red meat supply chains. It aims to understand the role and potential impact of implementing low-cost information technologies for responding to these challenges both within the individual firm and at different points along the red meat supply chain. Based on evidence gathered from this exploratory study, this will develop an alternative framework for small business to more easily implement some low-cost mobile technologies in their supply chain at different points to enhance traceability and potentially for responding to some of the critical challenges it faces.

This exploratory research is underpinned by an interpretivist epistemology and subjective ontology. The research strategy involves the conduct of four case studies involving 9 small businesses operating in Tasmania's red meat industry supply chain. The case studies are described as follows: (i) **Case study 1 (pre-slaughter beef supply chain segment)-**The supply chain comprises of 2 small businesses, and they include: (a) farmer/cattle transport (1 participant); and (b) saleyard operations (2 participants); (ii) **Case study 2 (post-slaughter beef supply chain segment)**: The supply chain comprises of 3 small businesses, and they include: (a) stock agent (1 participant); (b) wholesale(1 participant); and (c) retail butcher (1 participant); (iii) **Case study 3 (lamb meat supply chain)**-The supply chain comprises of 3 small businesses, and they include: (a) Lamb farmer/transport (1 participant); (b) meat processor (1 participant); and (c) cold chain/retail butcher (2 participants); and (iv) **Case study 4 (retail butcher)-**This case study involved only 1 retail butcher(1 participant) aligned to a beef supply chain in Tasmania.

Each of the four cases is structured in a three-phased approach of pre-intervention (baseline), technology intervention, and post-intervention (evaluation). The pre-intervention phase itself involves three steps, namely: (a) industry familiarisation; (b) supply chain mapping and technology audits; (c) and baseline data collection. The technology intervention phase involved the development and implementation of some low-cost mobile wireless technologies aimed at enhancing visibility and traceability in different segments of the red meat supply chain, and these segments were selected based on requirements identified in Phase 1. The post-intervention evaluation phase involved the collection of feedback from the small businesses that participated in the baseline mapping and technology intervention phase to understand the role and potential impact of enhanced traceability in their business and along their supply chains.

In framing the approach, the research utilised a heuristics framework adapted from the work of Caridi et al., (2010) to guide the quantitative baseline data collection on each participant's level of visibility to the potential traceability challenges faced in their supply chain segment. The framework utilises three significant information quality (IQ) criteria, namely: (i) *accessibility, (ii) freshness and currency, and (iii) accuracy*. The research has generated some key findings across the three-phased investigation, including:

a. Issues relating to small business technology awareness, cost of technology implementation & training, and technology complexity were not found to be significant barriers facing small businesses in enhancing their traceability. Although several studies have reported extensively on these challenges (Hardt, Flett et al. 2017, Lewis and Boyle 2017), this research reveals that these factors were not the significant inhibitors to traceability improvement. Instead, it was continued small business owners perception of the limited value/benefit of enhancing their traceability beyond merely compliance paper-based approaches that remained the primary inhibitor.
b. Implementing low-cost mobile technologies were perceived to have negative impacts amongst some of the small businesses because they viewed the interventions as contributing to (1) unnecessary information overload; (2) higher accountability expectations that may damage the long term supply chain relationships built over time; (3) new avenues for opportunistic behaviour from other actors due to gaining access to new data; (4) potential for incorrect and subjective interpretation, and unwarranted feedback from other actors without understanding the context of the supply chain and the difficult nature of the job.

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IX LIST OF ACRONYMS

Acronym	Explanation
2D	2Dimension
ABS	Australian Bureau of Statistics
ACMA	Australian Communications and Media Authority
AgVet	Agricultural Veterinary
AIMQ	Assessment Methods for Information Quality
ALT	Activity, Lying, and Temperature
AMIC	Australian Meat Industry Council
Android OS	Android Operating System
Apple iOS	Apple operating System
AUS-MEAT	Authority for The Uniform Specification of Meat and Livestock
BID	Bovine Identification Document
COC	Chain Of Custody
CTE	Critical Tracking Events
DNA	Deoxy-Ribonucleic Acid
DPAC	Tasmania’s Department of Premier and Cabinet
DPIPWE	Department of Primary Industries, Parks, Water and Environment
EIS	Electronic Identification System
EPC	Electronic Product Codes
EU	European Union
EVAO	Estimated Value of The Agricultural Operation
FTS	Food Traceability System
GDP	Gross Domestic Product
GMOs	Genetically Modified Organisms
GPS	Geographical Position Systems
GPS	Global Position Systems
GS1	Global Standard 1
GSM	Global System for Mobile Communication
HREF	Human Research Ethics Committee
HTML	Hyper Test Mark-Up Language
ICT	Information and Communication Technology
IDEF0	Integrated Definition Method
IoT	Internet of Things
IQ	Information Quality
IS	Information System
IT	Information Technology
KDE	Key Data Elements
LPA	Livestock Production Assurance
LPA NVD	LPA National Vendor Declaration
MEMS	Microelectronic Mechanical Sensor
MLA	Meat and Livestock Australia
NFC	Near Field Communication
NLIS	National Livestock Identification System
OEM	Original Equipment Manufacturers
OUOD	One-Up One-Down

QR	Quick Response Code
RFID	Radio Frequency for Identification
SCOR	Supply Chains Operations Reference
SEM	Structural Equation Modelling
SMEs	Small and Medium-Sized Enterprises
SMS	Short Messaging Service
SNP	Single Nucleotide Polymorphic
TAM	Technology Acceptance Model
TTI	Time Temperature Integrators
VSM	Value Stream Mapping
WSN	Wireless Sensor Networks
XML	eXtensible Markup Language

DEFINITION OF TERMS

Terms	Definition
Traceability	"The ability to trace the history, application or location of that which is under consideration. When considering the product (3.4.2), traceability can relate to the origin of materials and part, the processing history, and the distribution and location of the product after delivery" (ISO (9001: 2000) Quality Management Systems definition) (Aung & Chang, 2014).
Transparency	"access to non-distorted, factual, relevant, and timely information on products along the supply chain"(Astill et al. 2019)
Visibility	"the extent to which actors within a supply chain have access to or share the information which they consider as key or useful to their operations"(Barratt et al. 2007)

Chapter 1

Introduction

1.1 INTRODUCTION

Changing consumer preferences and enhanced food safety requirements in the food industry have increased the need for businesses to implement traceability. For small businesses, finding ways to respond to these changes using traceability has proven to be difficult due to the high cost of implementation, lack of awareness and limited technical know-how. The situation is, in part, due to the complex networks involving numerous stakeholders, including third party providers at different stages along red meat production and consumption value chains. This complexity contributes to the fragmentation of information impacting on the visibility of traceable links between product and information flows along supply chains. In red meat supply chains, fragmentation has been found to result in multiple traceability risks and challenges related to provenance, meat safety, meat quality/authenticity, and animal welfare. Most existing approaches for enhancing red meat traceability along the supply chain have been developed and implemented for large businesses primarily working in more integrated supply chains. Few approaches have been developed and implemented with small businesses in red meat supply chains (Zhang et al. 2014), and to-date many Australian businesses continue to face multiple challenges in maintaining traceability (Mirowski & Turner et al. 2014). However, with the emergence and increasing availability and usability of low-cost mobile technologies, opportunities for their deployment with small businesses in agri-business supply chains are emerging.

The purpose of this study is to explore traceability challenges amongst small businesses and to understand the role and potential impact of specific low-cost mobile technologies for responding to these challenges in red meat supply chains. The remainder of this chapter is divided as follows:

- Section 1.1.1 presents the background of the study, with a focus on the Australian red meat industry and the many socio-technical challenges identified along the supply chain. Based on the analysis of these challenges, it discusses the increasing importance of implementing traceability as one way of responding to some of the challenges faced.
- Section 1.2 describes the role and potential impact of information technology in traceability in the red meat supply chain.

- Section 1.3 presents the summary of research gap that thesis aims to fill through the conduct of an exploratory study.
- Section 1.4 presents the location of the research. Section 1.5 presents the research aims and objectives. Section 1.6 presents the research questions guiding the approach to this exploratory study. Section 1.7 presents the methodological approach utilised in this study. Section 1.8 presents the key contribution of this work. Section 1.9 presents the thesis outline for the remainder of this study.

1.1.1 BACKGROUND

The red meat[1] industry is one of Australia's most important agricultural enterprises. It employs more than 200,000 workers, and this translates to at least 2.9% of the country`s total employment (MLA,2017)[2]. Australia's red meat and livestock industry value add was $18.5 billion in 2017-18 and accounted for approximately 1.5% of Australia's key industry total industry value-add in the same year[3]. Sheep and beef meat are the two most popular red meat product produced for domestic and export market consumption. While beef is the most famous export, other types of red meat from Australia are also in high demand in the export market, and they include mutton and goat meat (World Atlas,2019).

In the last two decades, the red meat sector in Australia is undergoing rapid change because of globalisation, and a highly competitive beef and red meat market (local and export) (Wang et al. 2019). While premium beef exports into major international markets have strengthened and continue to experience sustained growth supported by rising middle-class income in export markets in the last decade (e.g. China, Korea, Japan), the domestic beef consumption on a per capita basis has declined steadily in this same period. This trend reflects changes in consumers' preferences for alternative proteins, particularly pork and chicken (Espinel et al. 2013). A similar study conducted by Ratnasiri et al. (2017) also reveals a steady decline in Australian per capita consumption of beef over the last decade, while at the same time the per capita consumption of chicken and pork has seen a significant increase.

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[1] In this thesis, the definition of red meat relates to beef and lamb meat only
[2] https://www.mla.com.au/globalassets/mla-corporate/prices--markets/documents/soti2018.pdf
[3] https://www.mla.com.au/globalassets/mla-corporate/prices--markets/documents/trends--analysis/soti-report/mla-state-of-industry-report-2019.pdf

Apart from the growing socio-technical challenges facing the red meat industry, there have been multiple scandals/scares occurring in many developed economies which have contributed to a decline in consumption and consumer trust over the last two decades. Prominent scandals include the Bovine Spongiform Encephalopathy (BSE) scare in Europe (Kim & Jeong 2018), Salmonella contamination of minced meat(Marshall et al. 2018), Escherichia coli O157: H7 contamination (Kakagianni et al. 2019), King Island sausage fraud and mislabelling[4], Horse-gate meat scandal (Stanciu 2015) and more recently the abrupt death of Australian beef cattle aboard a ship to overseas market[5]. While some of these have been deliberate, others were discovered to be related to lack of visibility, accidental or poor compliance (Brooks et al. 2017).

Understanding how red meat industry businesses can adapt and respond to these challenges faced in their supply chains have been a significant focus of research in Australia over the last twenty years (CSIRO, 2016)[6]. One area that has been recognised as having the potential to play a positive critical role is the implementation of traceability. While complex to define, traceability involves enhancing the quality and transparency of information related to material product flows and transformations along the supply chain with the aim of adding or retaining value (Adam et al. 2016). Traceability can also be defined as the ability to track and trace the movement of physical products/foods along stages of production, processing, and distribution in supply chains (Monjardino de Souza Monteiro et al. 2004). Implementing traceability has been a significant focus of much research work with numerous models, frameworks, tools and techniques published (Karlsen et al. 2013).

In the red meat supply chains, traceability has been defined as the to the ability to identify the origin of animals, their meat products as far back in the production chain in order to ascertain ownership, identify parentage, assure food safety, and/or assure compliance (e.g., for source-verification, process-verification, production practice-

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[4] https://www.heraldsun.com.au/news/law-order/victorian-butcher-snagged-in-false-meat-claim/news-story/dff3ffe4a66bc794e4e9a693410c2751

[5] https://thewest.com.au/business/agriculture/sixty-wa-cattle-die-aboard-maysora-export-ship-after-unloading-delay-in-israel-ng-b881233067z

[6] https://pure.aber.ac.uk/portal/files/29623611/on_the_farmers_radar_top_10_tech_trends_for_2019_final.pdf

verification, branded-beef program constraints, beef export verification, authenticity management (Smith 2000). Opara (2003) and Mirowski & Turner (2014) suggested seven dimensions of traceability, and these include product, process, input, genetic, disease and pest, measurement and consumption. These dimensions provide a holistic approach for understanding how to identify, evaluate, and respond to the critical challenges impacting the red meat industry and supply chains.

The research literature provides evidence that while large businesses have been able to implement traceability effectively using new innovative technologies, many small businesses continue to experience difficulties (Mattevi et al. 2016a). From a practical perspective, it can be argued that this situation for most small businesses, is in part due to their limited capital and human resources, lack of adequate skills and understanding on how to apply these systems (Kärkkäinen et al. 2005). From a research perspective, it has also been suggested that the existing models, tools, and frameworks advocated for implementing traceability have been developed primarily for large businesses whose context are different from small businesses in their supply chain (Mertins et al. 2012; Shirani et al. 2015). Small businesses in the red meat industry usually operate in complex multi-tiered networks involving numerous stakeholders along the red meat production and consumption value chains(Adam et al. 2016; Hoyer 2008; Münch et al. 2013). This complexity is often accompanied by poor coordination between participants, and the limited integration of information and product flows across various organisations. This complexity is further heightened by the fact the smallest businesses exhibit limited technological use and adoption in their traceability across functional segments with paper documentation still very common (Parreño-Marchante et al. 2014). Due to these complex issues, most small businesses have tended to only focus on minimum information sharing with immediate industry partners in what has been called a one-up-one-down (OUOD) siloed strategy (Nishantha et al. 2010). Unfortunately, this traceability in insufficient for responding to many of the critical challenges impacting the industry. In this context, it is perhaps not surprising that the ability for small businesses to understand and respond to traceability risks and challenges remains relatively low in their supply chains (Brooks et al. 2017).

The traceability challenges impacting many small businesses in the red meat supply chains relate to critical issues of :(a) Provenance: Retention of identity from the time an animal is born to when it is presented to the consumer as a cut of meat; (b) Food safety: whereby the consumer must be able to eat the meat without fear of adverse health effects, and, (c) meat quality/authenticity: provides consumers' with confidence that the meat he or she is eating is in fact what it is purported to be on the label (Manning et al. 2019; Shackell 2008). More recently, an additional traceability challenge of increasing importance is the issue of animal welfare, i.e. ascertaining and assuring consumers that the animals have been treated humanely on the farm, during transportation, and before slaughter (Vanhonacker et al., 2007). This issue of animal welfare continues to receive a lot of media attention, and research shows that many consumers utilise animal welfare information to inform their expectations about the meat products they purchase and consume (Napolitano et al., 2010). Significantly, studies have also found that the welfare of animals is also directly related to meat quality and safety (Blokhuis et al. 2008).

1.2 INFORMATION TECHNOLOGY

In the red meat industry, the earliest approach for implementing traceability in the red meat industry has been through paper-based techniques, ear tattoos, marking, and paper-based passports (Ammendrup et al. 2001; Bowling et al. 2008). However, many studies conducted with these methods have proven their inefficiencies and limited capacity to respond to the present challenges the industry faces in term of traceability (Gooch et al. 2015). As a result, new innovative technologies have been developed that provide new capabilities to enhance the transparency of information and material flows the along the chain to support traceability from farm to retail (Feng et al. 2013). Specific examples of these technologies include electronic identification technologies(Shanahan et al. 2010), biometric technologies (Fernández et al. 2013) and more recently, the use of blockchains (Sander et al. 2018). These technologies play essential roles in traceability, namely: (1) risk management and food safety; (2) control and verification; (3) value chain management and efficiency; (4) provenance and quality assurance; (5) and consumer engagement. Other technologies such as the barcode, quick response (QR) code solutions and devices have been widely implemented in different segments of the red meat supply chain to improve identification and meat traceability (Tarjan et al. 2014).

More recently, there have been several sophisticated traceability technologies that have begun to emerge with capacities for authentication, monitoring and food verification. These include biometric and facial recognition technologies(Fernández et al. 2013), integrated wireless sensor network(Ko et al. 2014), electronic nose (Cayot 2007), and intelligent sensing and smart packaging systems (Sohail et al. 2018). Also, the availability and affordability of low-cost mobile technologies and portable devices have increasingly become popular in traceability studies (Pigini et al. 2017). For example, mobile devices equipped with integrated chips such as accelerometers, temperature sensors, geographical positions systems (GPS) sensors have been utilised to capture micro-environmental parameters which can be used to sense and communicate food safety to consumers (Trebar et al. 2013). New portable pedometric sensors provide increased visibility and traceability of animal welfare by capturing activity patterns which have proven useful for early detection of illness and visibility to animal reproductive cycles (Kwong et al. 2009).

Significantly, it has also been suggested new technologies in traceability can lead to a significant positive impact on the supply chain (Bottani et al. 2008). For example, Sarac et al. (2010) suggested that implementing RFID technologies can lead to increased supply chain performance through the reduction of inventory losses, increase in efficiency and speed of supply chain processes, and improvement in information accuracy. Some authors believe that RFID technology can lead to labour reduction throughout the better supply chain planning and organisation, and waste reduction(Michael et al. 2005). Kwong et al. (2008) found that implementing sensing systems on cattle in the farm can lead to a reduction in the cost of engaging in highly labour-intensive visual monitoring activities on the farm, such as extensive animal observation to detect and monitor illness or conditions such as calving or oestrus. In the areas of low-cost IT implementation, other traceability studies reveal varying results regarding the potential impact on the supply chain (Sayogo 2018; Tamm et al. 2016; Tsai et al. 2014). These studies conclude that low-cost wireless and mobile technologies can enhance consumer awareness and engagement (Araujo et al. 2015), improved consumer food experience (Hegen et al. 2015), and increase awareness of impacts of food consumption on environment and sustainability(Nghiem et al. 2016). Mobile technology is a category of information technologies that is underpinned by mobility, portability, and accessibility through the internet or Bluetooth® wireless connection[7]. Current devices in this category include tools such as smartphones, tablets, iPods, and laptops, and this list continues to increase as new mobile-friendly devices continue to emerge[8]. Within research literature, interests in the utilisation and application of low-cost mobile technologies for supporting traceability in red meat supply chains have increased, partly due to wide of benefits they provide to businesses such as lower cost of acquisition, reduced technology overhead, and ease and portability of implementation in supply chains(Kassahun et al. 2014). In red meat supply chains, numerous studies highlight multiple roles that mobile technologies can play to support traceability along the supply chain including remote monitoring through the internet of things (IoT) technologies (Maksimovic et al. 2015); food authentication through Near Field Communication (Badia-Melis et al. 2016); and development of new mobile applications for supply chain management (Chantzic et al. 2013).

Low-cost mobile technologies have also been utilised to provide real-time logistics information to supply partners, increase consumer awareness and improve compliance to government food safety regulations along the food supply chain (Foster et al. 2018). In the area of animal welfare, modern mobile technologies are equipped with sensing functionalities that make it possible to develop portable mobile farming information system for farm health management and traceability along red meat supply chains(Liu et al. 2016). Implementing low-cost mobile technologies such as native apps can support the digital transformation of food supply chains (Pigini et al. 2017), and potentially to enhance safe food management behaviour amongst meat consumer (Bamgboje-Ayodele et al. 2018). These studies highlight the proven ability and utility of low-cost mobile technologies to play multiple roles in supporting traceability both within individual firms and also along the supply chains (Bentivoglio et al. 2016). This study will explore how low-cost mobile technologies can be utilised and deployed amongst small businesses in the red meat supply chain to support traceability and for responding to some of the critical challenges faced at different points in the chain. It is anticipated that the exploratory research will also generate a framework to support a better understanding

[7] https://www.igi-global.com/dictionary/mobile-strategy-business-solution/18956
[8] https://sites.psu.edu/mobilelearninglau/2014/05/25/definition-of-mobile-technology/

of the extent to which low-cost mobile technologies can impact positively on traceability amongst small businesses in red meat supply chains.

1.3 SUMMARY OF RESEARCH GAPS

Understanding how to improve traceability in terms of enhancing visibility and alignment of information and product flows in food supply chains amongst small businesses has emerged as an area of increasing importance. Previous research has suggested the need for greater vertical coordination within red meat supply chains in order to reduce risk and uncertainty and foster an environment of innovation and value creation (Canavari et al. 2010). Other authors have suggested approaches that have included the use of mathematical models, simulation, and analytical modelling techniques (Dupuy et al. 2005), and more recently the use of conceptual frameworks and reference models to harmonise and standardise data along food chains (Zhang and Bhatt 2014). Some authors have suggested the use of integrated reference framework (Storøy et al. 2013), ontology derived framework Pizzuti et al. (2014), business modelling framework (Verdenius 2006), and the audit framework developed by Bendaoud et al. (2012). These models and frameworks, while helpful, assume linear supply chains that are vertically integrated and, in most cases, involve primarily large businesses. For small businesses, limited visibility and alignment of information and product flows beyond immediate supply chain partners has remained a problem and is not adequately addressed in these widely cited models/frameworks.

Most existing approaches for enhancing red meat traceability and responding to many of these challenges along the red meat supply chain have been developed and implemented for large businesses primarily working in more integrated supply chains. Increasingly the deployment of information technologies aligned to traceability frameworks has been used by many large organisations (Karlsen et al. 2013), with evidence highlighting their proven effectiveness in many parts of the red meat industry supply chains (TraceFood, 2009). Unfortunately, most small businesses also face challenges related to understanding, implementing and benefiting from these technology tools and frameworks primarily because of their relatively high cost of implementation, limited technological awareness and know-how (Harindranath et al. 2008), limited resources, and inability to influence their utilisation within their supply chains as a whole (Bosona et al. 2013; Hardt et al. 2017).

Caridi et al. (2010) proposed a systematic and structured approach that might be suitable for adaptation to small businesses and use in more fragmented supply chains. Their approach utilises visibility for understanding how to improve traceability in fragmented non-linear supply chains. This involves measuring visibility in terms of the amount and quality of useful information when compared to the total information that could be exchanged between nodes in a supply chain (Nguyen et al. 2017). Using three information quality criteria and metrics, namely *completeness, accuracy, and freshness/currency* the authors were able to identify potential information quality gaps in traceability along a fragmented supply chain where IT can be most effectively and practically deployed to enhance visibility and capacity for traceability along the supply chain. This approach also opens the possibility of better analysing the potential impact of visibility improvement on the supply chain. However, this does assume that adequate baseline data on the total amount and quality of information can be captured. Building on the work of Caridi et al. (2010), this research has adapted the heuristic framework for guiding the conduct of some field studies aimed at exploring traceability challenges facing small businesses at different points along red meat supply chains in Tasmania. However, with the emergence and increasing availability and usability of low-cost mobile technologies, opportunities for their deployment with small businesses in agri-business supply chains are emerging. The purpose of this study is to explore how and to what extent can the implementation of low-cost mobile technologies enhance visibility and capacity for traceability amongst small businesses in responding to the critical traceability challenges being faced at different segment of the red meat supply chain.

This research study aims to explore traceability challenges facing Tasmanian small businesses operating in fragmented red meat supply chains. It aims to understand how and to what extent can specific low-cost mobile technologies support enhanced traceability at different points in the chain. Based on evidence gathered from this exploratory study, this will develop an alternative framework for small business to more easily implement some low-cost mobile technologies in their supply chain at different points to enhance traceability and potentially for responding to some of the critical challenges it faces.

1.4 LOCATION OF RESEARCH

This exploratory study is located in the intersection of four research domains, and these comprise of small businesses, red meat supply chains, traceability, and information technology. The research context in the outer section is small businesses.

Figure 1 below shows the intersection and location of this research and highlights each of the research domains. It shows that in the domain of red meat supply chains, the research aims to map a lamb and beef supply chain to explore traceability challenges that are impacting small businesses in their capacity to properly align information and material flow at different segments. In terms of IT, the research will propose and implement specific low-cost mobile technologies to enhance visibility and capacity for traceability in responding to some of the critical challenges faced by small businesses at different points along the red meat supply chain. Based on evidence gained from the intervention, the research will explore the role and potential impact on traceability and supply chain amongst small businesses involved.

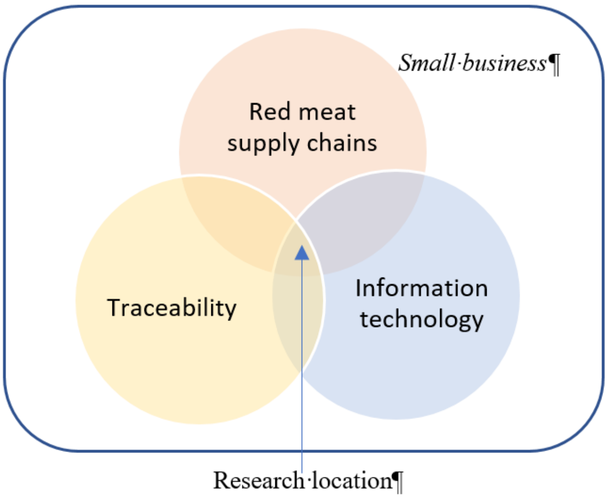


Figure 1. Location of the research study

In terms of traceability, the research focuses on four critical challenges potentially impacting traceability amongst small businesses in red meat supply chains, and these comprise mainly of meat provenance, meat safety, meat quality/authenticity, and animal welfare

1.5 RESEARCH AIM AND OBJECTIVES

This research aims to explore traceability challenges amongst small businesses in red meat supply chains. The purpose of this exploratory study is to understand the role and potential impact that specific low-cost IT can in responding to the critical challenges facing small businesses in their supply chains at different segments. The key objectives of this exploratory research study are to:

1. Understand the traceability challenges facing Tasmanian small business operating within the red meat industry;
2. To propose and implement some low-cost mobile technologies for responding to some of the critical challenges faced; and
3. To evaluate the role and impact of some low-cost information technology interventions on traceability internal to individual firms and external along the supply chain.

1.6 RESEARCH QUESTIONS

The research questions that have been proposed to guide this exploratory study are as follows:

1) How can low-cost mobile technologies be utilised and deployed amongst small businesses in red meat supply chains to support traceability, and for responding to challenges faced?
2) What criteria do small businesses in red meat supply chains use in evaluating the role and potential impact of low-cost mobile technologies in supporting traceability, and for responding to challenges faced?
3) How can a small business traceability framework be developed to support the implementation and evaluation of low-cost mobile technologies to support traceability, and for responding to challenges faced?

1.7 RESEARCH METHODOLOGY

The research methodology is a multiple case study of 9 small businesses operating in the major segments of the Tasmanian red meat (beef and lamb) supply chain, and these include farmer, animal transport, saleyard, stock agent, meat processor, wholesale, cold chain transport, and retail butcher. The multiple case study approach provides the opportunity for the researcher to explore traceability amongst small businesses in its natural context, identify new patterns within and between cases involving the potential challenges faced, and to generate a more holistic understanding of the role and potential impact of mobile technologies along the supply chain. This approach is also open up new possibilities for the generation, refining and validation of a framework based on multiple case study methodology (Noor 2008).

The research uses multiple case studies of small businesses operating within the Tasmanian red meat industry in both lamb and beef supply chains. The strategy is organised in three phases, namely pre-intervention, intervention and post-intervention. The pre-intervention phase is organised into three steps. Firstly, the research conducted a preliminary study and engagement with 7 major stakeholders operating the regulatory and non-regulatory sector of the Tasmanian industry. The purpose of this familiarisation was to understand some of the critical traceability challenges potentially impacting Tasmanian small businesses from a regulatory perspective. The participants were selected from the Department of Primary Industries, Parks, Water and Environment (DPIPWE), Australian Meat Industry Council (AMIC), and Hobart City Council. The key department divisions include *Biosecurity and Traceability, Animal Brands, Meat Safety, Animal Welfare, Agricultural Veterinary (Agvet) and Chemicals, and Food Standards and food hygiene and meat safety*.

Secondly, participants were selected from 9 small businesses operating in different parts of the red meat supply chain to participate in the mapping phase, who following ethics approval, participants were invited via telephone to engage in face-to-face interactions across the three stages of the research. The initial participants were drawn from the following segments: farmer, saleyard, processor, cold chain transport, and retail butchers In phase one, the aim was to map information and material flow in their respective supply chain segment as well as identify some of the potential traceability challenges faced, and to assess their level of visibility to these challenges in their respective segment. The visibility assessment focused on four key areas, namely meat provenance, meat safety, meat quality/authenticity, and animal welfare. Participants provided suggestions on the critical challenges faced and their potential information quality criteria which they considered useful for their supply chain operations based on the heuristic framework presented to them.

In Phase 2 (technology intervention phase) the research develops and implements a number of mobile applications and wireless sensors for implementation in their supply chain segments aimed at enhancing the amount and quality of information needed to facilitate traceability and greater visibility related to some of the risks and challenges being faced. The participants contributed to the selection and deployment of mobile technologies in this phase. The technologies include the implementation of:

a. A Cow activity monitoring system to improve visibility to changes in animal behaviour, support oestrus detection and potential illness of cattle in free-range conditions in the farm;
b. A Barcode carcase labelling system to enhance carcase identity preservation after slaughtering, and a portable Bluetooth wireless system for enhanced visibility to abattoir temperature during processing and in the cold room.
c. A Portable temperature tracking system to support cold chain monitoring and temperature traceability along the lamb supply chain.
d. 3 native and mobile web meat provenance verification system for 3 local retail butchers to enhance the amount and quality of information needed to improve verification of meat provenance, product differentiation and retail marketing in the store.

In phase 3 (post-intervention/feedback), the participants that were involved Phase 1 and Phase 2 were contacted and interviewed via face-to-face interactions to understand how and to what extent had the implementation of the low-cost mobile technologies impacted their capacity to respond to risks and challenges faced individually and along the supply chain. Based on evidence gathered from this study in all three phases, the research generated a framework for understanding how and what mobile technologies can be deployed in the context of small businesses operating in the red meat supply chain as well as identified key factors that contribute to or inhibit their utilisation amongst small businesses.

The research data collection involved mixed-method across the three-phased approach. In the qualitative phase, the research utilised semi-structured interviews, document and document reviews as the primary methods for obtaining field data from the case studies. Each participant was interviewed for approximately 60-90mins and additional documents related to interview responses were obtained for triangulation purposes and to improve the reliability of findings. In the qualitative phase, the heuristics framework through structured questionnaires were deployed. Quantitative data involved the collection of subjective assessment of information quality criteria aligned to their prioritised traceability needs, potential risks and challenges being faced in their supply chain.

Data analysis were performed using qualitative and quantitative techniques. Qualitatively, voice transcripts derived from semi-structured interviews were coded and analysed thematically to generate key themes that emerged from the data. Additionally, the paper documents derived from field investigation were analysed using both document and context analysis procedures. Important data elements required for implementing traceability and for enhancing information quality were obtained using both procedures. The questionnaires were analysed and interpreted using the assessment formulae adapted from the work of Caridi et al., (2013). This quantitative self-assessment also allowed for comparison with participants in Phase 3 evaluation.

The interpretation and discussion of findings followed a subjectivist and interpretivist perspective. This means that in exploring a phenomenon, while the researcher has obtained subjective data based on individual views and experiences from each participant, the researcher is forced to attribute personal interpretations of the experiences and phenomena in discussing each finding both individually and collectively. In the next section, the key contributions of this research work are discussed.

1.8 KEY CONTRIBUTIONS

The key contributions of this research work are summarised at the substantive, methodological, and conceptual levels:

a. Substantively, the research has generated new data and insights from multiple case studies highlighting potential traceability challenges facing Tasmanian small businesses in their supply chains at different points. Based on technology interventions and post-intervention feedback, the research also presents new findings that highlight the role and potential impact of IT for enhancing traceability amongst small businesses in the Tasmanian red meat industry. As part of the substantive contribution of this work, the research has also developed some new mobile applications that have been adopted by some of the exploratory research participants as part of their on-going business practices. These applications include (a) a consumer verification app integrated with quick respond (QR) codes and near field communication technologies (NFC) authentication(Available for iOS and Android devices); (b) Chill-Verify App: an Android mobile application to improve transparency to temperature-controlled logistics in retail butcher supply chains (Android); (c) A web app/content management system to support aggregation and capture of unique data element required for demonstrating evidence of provenance through the mobile phone.

b. Methodologically, the research presents a three-phased research strategy to understand and subsequently evaluate the role and potential impact of low-cost IT on traceability amongst small businesses operating in red meat supply chains. This approach makes possible the use of both qualitative and quantitative impact assessment of IT in traceability. Based on the evidence gathered from the field case studies, the research has refined the heuristic framework initially adapted from Caridi et al. (2014) to enable small businesses to identify and implement IT in areas of potential positive impact along the supply chain. It is anticipated that this traceability framework can be adapted to other fragmented supply chains in the agro-food industry.

c. Conceptually, the research has utilised an alternative traceability and visibility conceptualisation that makes use of minimum traceability requirement(Amuno et al. 2018), in order to identify and select segments for mapping and technology intervention and post-intervention study.

The research has generated new key findings across the three-phased investigation, including:

a. Issues relating to small business technology awareness, cost of technology implementation & training, and technology complexity were not found to be significant barriers facing small businesses in enhancing their traceability. Although several studies have reported extensively on these challenges (Hardt, Flett et al. 2017, Lewis and Boyle 2017), this research reveals that these factors were not the significant inhibitors to traceability improvement. Instead, it was continued small business owner’s perception of the limited value/benefit of enhancing their traceability beyond merely compliance paper-based approaches that remained the primary inhibitor.

b. Implementing low-cost mobile technologies were perceived to have negative impacts amongst some of the small businesses because they viewed the interventions as contributing to (1) unnecessary information overload; (2) higher accountability expectations that may damage the long-term supply chain relationships built over time; (3) new avenues for opportunistic behaviour from other actors due to gaining access to new data; (4) potential for incorrect and subjective interpretation, and unwarranted feedback from other actors without understanding the context of the supply chain and the difficult nature of the job.

Based on these results, the research has generated a framework that makes it possible to more effectively determine the most appropriate points along the supply chain to implement low-cost mobile solutions and identify the likely positive and potentially negative impacts from improved traceability. Aligned with these findings is the observation that the main barriers to mobile technology utilisation for traceability remains socio-organisational perceptions amongst Tasmanian small businesses rather than technical or cost-based factors.

a. There were markedly different reactions amongst participants involved in the technology intervention both within individual firms and between different firms. For example, amongst butchers, there have been some who have enthusiastically adopted and now use the trial systems and are now seeking to invest and implement them into the future. Other butchers including the meat processor, however, have struggled and continue not to see value in improving their traceability and capacity for responding to challenges or in generating new opportunities.
b. Assessing the role and impact of implementing some low-cost mobile systems in farm settings proved to be particularly challenging. This challenge was because the experiment faced several barriers including difficult topological terrain, poor internet connectivity, abrupt changes in grazing location, the spatial distribution of livestock's, antennae sensitivity to sensor tags due to physical barriers in the farm. The studies of Handcock et al. (2009) and Turner et al. (2000) have also reported similar challenges facing the effective implementation of the sensing technologies on cattle on the farm. This study confirms those challenges and has suggested alternative measures for future implementation.

1.9 THESIS OUTLINE

The outline of the remaining chapter of this thesis is presented as follows:

- Chapter 2 provides a literature review of the key research domains involved with this study. The focus is to explore the red meat industry and the associated traceability challenges and risks being faced along the chain. Based on this review, the research explores existing IT alternatives capable of being applied to traceability in the red meat supply chain and their role and potential impact in responding to traceability challenges.
- Chapter 3 presents the main research methodology. It describes the philosophical approach adopted for this study, the research strategy, and then research design used to guide data collection. The research strategy is a three-phased strategy of pre-intervention, intervention, and post-intervention. The research design is a multiple case study design involving four traceability case studies. Data collection involved a mixed-method approach consistent with the use of a case study design, and data analysis was conducted using thematic analysis procedures. Multiple sources of data were used, and these include primary data- using semi-structured interviews, and secondary data field notes, document reviews, archival records, online reports, website information and business fliers.
- Chapter 4 presents the analysis of findings from the industry familiarisation phase and preliminary findings from the supply chain mapping exercise. Chapter 5 presents the analysis of findings for case study 1. Chapter 6 presents the analysis of findings for case study 2. Chapter 7 presents the analysis of findings for case study 3. Chapter 8 presents the analysis of findings for case study 4. Chapter 9 presents the cross-case analysis of findings from multiple case studies. For each case study findings presented in this thesis, the core categories that emerged from each key theme explored in this study, following coding and thematic analysis of data, are presented and organised using the three-phased approach, namely: pre-intervention (industry familiarisation, supply chain mapping), technology intervention and post-intervention.
- Chapter 10 presents the interpretation and discussion of findings. The key insights from each case study explored are discussed and interpreted with the

research literature in mind. This is organised using the three-phased approach. Based on the new insights generated in this chapter, a small business traceability framework is generated to guide other studies involving the implementation of low-cost IT along fragmented red meat supply chains with small businesses to enhance traceability at different segments.

- Chapter 11 provides a synthesis of the research findings. Then it discusses how this exploratory research answers the research questions and provides a conclusion and recommendations for further investigation.

Chapter 2

Literature review

2.1 INTRODUCTION

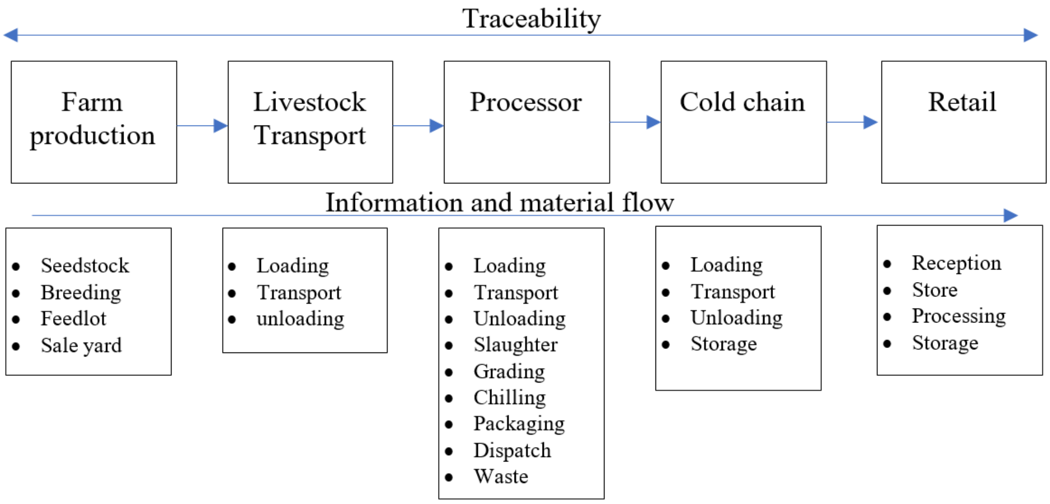
This chapter presents a literature review of the research domains that fall within the scope of this study. The literature reviews are important because it provides the necessary background needed to understand the remaining chapters of the thesis. The summary of the key sections of this chapter is as follows: Section 2.2 discusses the Tasmanian red meat sector and presents a generic map of the red value chain, and reviews some of the critical challenges it faces concerning traceability. Section 2.3 reviews the concept of traceability, dimensions of traceability, and forms of traceability. Section 2.4 reviews the research literature on the role of IT in traceability along the red meat supply chain for beef and lamb. Section 2.5 discusses the NLIS system of traceability in the red meat industry and focuses on regulatory framework underpinning the system at the state level in Tasman. Section 2.6 reviews literature on potential traceability challenges impacting the red meat industry supply chains. Section 2.7 discusses approaches being used in previous related studies for mitigating traceability challenges impacting red meat supply chains. Section 2.8 discusses the small business sector of the red meat industry and the barrier to IT and full traceability in the supply chain. Section 2.9 reviews extant on models and frameworks for implementing traceability and suggests an alternative approach using visibility assessment in the small business context. Section. 2.10 reviews the literature on theoretical underpinnings of food traceability. Section 2.11 reviews the literature on information quality approach for enhancing traceability along the red meat supply chain. Section 2.12 reviews existing frameworks for mapping traceability in red meat supply chains, and proposes an alternative framework for mapping the red meat supply chains in this study. This chapter ends with the key findings from the review of literature in Section 2.13.

2.2 THE TASMANIAN RED MEAT INDUSTRY

The Tasmanian red meat industry is known around the world for producing some of the finest and highest quality meat products in the world. Tasmania's red meat is known in many export markets for their 'clean and green' characteristics. This reputation is underpinned by (a) A ban on hormone growth promotants and a moratorium on genetically modified organisms (GMOs); (b) low-cost, high-quality, primarily pasture-based production; and (c) Relative disease freedom; (d) the development of differentiated brands and products based on a quality proposition(Hall 2013). Beef and lamb are the most important red meat product, contributing more than $2billion in Gross Domestic Product (GDP) and employing more than 2000 people directly and many more indirectly employed in remote, rural and regional areas[9]. There are around 3000 farms carrying a total of 446,000 beef cattle, and 1800 farms carrying a total of around 1.99 million sheep in Tasmania[10]. The Tasmanian industry is export-oriented with more than 90% of red meat products sold to markets in Asia, Europe and North America. Domestically, Tasmanian red meat products are sold locally in retail shops, butcher stores, hotels and speciality food stores.

2.2.1 THE RED MEAT SUPPLY CHAIN

The red meat supply chain can be divided into five main phases of operations involved in the production of meat from farm to retail and these covering farm production, Livestock Transport, Processor, Cold chain, and Retail (Ding et al. 2014; Jie 2009). Figure 2: below shows a generic supply chain for red meat (beef and sheep). It shows the cross-functional businesses entities operating in the chain from farm to final retail. In the next section, these five phases of operations are discussed in the context of some of the critical risks and challenges being phased in the red meat industry.



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9 http://safemeat.com.au/_literature_65326/Australia's_Red_Meat_and_Livestock_Industry_Biotechnology_Policy_-_Detailed_Paper

10 https://agwhitepaper.agriculture.gov.au/sites/default/files/SiteCollectionDocuments/IP363%20Regional%20Development%20Australia%20-%20Tasmania%201.pdf

Figure 2: Supply chain map of generic red meat (beef and lamb) supply chain

2.2.1.1 CRITICAL CHALLENGES IN THE RED MEAT SUPPLY CHAIN

The farm production segment includes activities such as seed stock generators, cow/calf producers, stockers/backgrounders, sale yard and feedlot operators (Jie et al. 2009). The seed stockers mainly sell genetic material (including embryos and semen) for use in artificial insemination or offer stud services for breeders. The goal of the seed stockers is to provide genetic breeds that meet specific physical and behavioural characteristics requested by the breeders or farmers[11]. These characteristics could include resistance to heat, temperament, meat quality, yield, muscling, and feed conversion rate. The breeder purchases seed stocks for artificial insemination or stud services from bulls to mate with cattle to wean and grow new calves or lambs. Breeding activities from newborn calves and lambs include feeding, weaning, pasture management, veterinary care, and animal health monitoring. Amongst these activities, one of the critical challenges facing the red meat supply chain is the possibility of chemical residue detection in meat products.

Chemicals are used intentionally at the primary production stage for several reasons, including pest and weed control and animal health. The administration of these chemicals on the animals or in their surrounding environment increases to possibilities for residue detection (Tilahun et al. 2016). Chemical residue detection is widely acknowledged as a major food safety challenge in the red meat industry (Mitchell et al. 1998; O'Keeffe et al. 2000). Chemicals are used intentionally at the primary production stage for several reasons, including pest and weed control and animal health. The administration of these chemicals on the animals or in their surrounding environment increases to possibilities for residue detection (Tilahun et al. 2016). There has been a lot of discussion within literature surrounding the factors that contribute to the vulnerability of red meat supply chains to chemical residues in meat products(Halldorsson et al. 2012). Most authors generally agree that the vast majority of cases are due to poor farm management practices, improper usage of chemical, and non-compliance to observing withholding period(Beyene 2016). The possibility of heavy metal contamination in meat products has been cited as a major risk and challenge impacting most red meat supply chains, especially in the farm

[11] https://www.pwc.com.au/industry/agribusiness/assets/australian-beef-industry-nov11.pdf

production segment. Animals can be exposed to a range of heavy metals such as Lead, Zinc, Arsenic, Cadmium and Copper. Sources of heavy metal contaminants have been linked to those that usually occur naturally in the environment, or can be captured from anthropogenic sources such as the combustion of fossil fuels, fertiliser input, use of antiseptics and disinfectants, industrial waste or exposure to contaminated feed(Makridis et al. 2012).

Livestock transportation phase includes activities such as load-in, road transport, and unloading activities at the sale yard or directly at the processor. Transportation is a stressful experience for most cattle and lamb (Ferguson et al. 2008). During transport, producers are concerned more about the welfare of cattle due to their exposure to a wide range of challenging stimuli(Grandin 2007). For example noise, vibration, social regrouping, crowding, climatic factors (temperature, humidity, and gases), restraint, loading and unloading, time of transit, and feed and water deprivation have been found to negatively affect the welfare of beef cattle during transportation (Ferguson et al. 2008). The mixture of these various stimuli can invoke further psychological distress with a resultant effect on meat quality known as dark cutting (Swanson et al. 2001). Other significant stressors during transport include animal loading and unloading activities, longer lairage times, and longer journeys (Gallo et al. 2003). Schuetze et al. (2017) identified 5 critical parameters that can be used to characterise and monitor welfare condition of animals along the supply chain and they are: microclimate environmental condition, loading density, duration of transport, quality of transport, and animal behaviour. Mixing of cattle and holding times at the abattoir also represent a critical control point during logistics operations as weaker animals are more likely to be distressed by stronger breeds during mixing and loading operations. Other risk factors that contribute to stress in cattle or sheep include animal age, group size, space allowance, and road condition.

The processing segment includes a range of transformation activities that begin with slaughtering, and then later value-adding activities such as deboning, grading, packing, storage; chilling. For beef and lamb, employing chilling parameters that minimise cold shortening (i.e. rapid chilling) is of the most significant importance (Savell et al. 2005). Inappropriate chilling regimes above 5^{o}C post-mortem affords opportunities for pathogenic bacteria to multiply on the meat leading to reduced shelf life, meat spoilage, and could expose consumers to public health risks (Gill et al.

1991). Low temperatures, minimal air movements and high relative humidity are critical parameters that are monitored in order to maximise storage life and minimise weight loss(James 1996).

The cold chain/logistics phase includes road transportation from the meat processor to the final destination, such as retail, restaurants, and speciality stores. An important phase in logistics is the cold chain transportation. This includes all the steps during which meat product is transported and in which period its temperature is maintained at or below 5ºC (Brizzi et al. 2013). During meat transport, ineffective chilling of meat during storage, distribution and retail can lead to a significant reduction in shelf life and early spoilage of meat (Nastasijević et al. 2017). As a result, the maximum temperature condition during cold chain operations in refrigerated trucks is set at 5°C. This temperature limit ensures the safety and maintenance of shelf life and quality of the red meat product until it reaches its final destination.

In the retail phase, further value-add activities can include disaggregation, packaging, storage and display for the consumer to view and purchase. It is known that shelf life, appearance, palatability, and sensory qualities are essential determinants that influence consumers perception of meat (Carpenter et al. 2001). Other extrinsic quality indicators such as the colour, marbling and tenderness have been found to impact consumers' choice and purchase decisions (Feuz et al. 2004). However, a number of challenges have emerged in recent times with regards to meat quality, and these include the possibility of product commingling, false labelling, and lack of proper speciation of ingredients add to meat products (Montowska,2010). These critical issues aligned to the meat product pose significant challenges to many red meat businesses in maintaining the proper alignment of information and material flows in the chain in order to ensure transparency in supply chain management of red meat.

Based on these critical issues, four important domains can be identified, and these relate to issues of meat provenance, meat safety, meat quality/authenticity and animal welfare. In responding to many of these critical issues and challenges faced in the chain concerning red meat supply chain management, interests in the utilisation and application of traceability have gained increased recognition. The next section presents the traceability concept and their role in enhancing the transparency of information related to these key domains.

2.3 TRACEABILITY

Traceability is a comprehensive concept used in many research domains in the food industry, and as a result, there is yet to emerge a uniform understanding and definition in the research literature(Van Dorp 2002). However, the two widely cited definitions of traceability are those of the International Standard Organisation (ISO 9001:2000) and the European Union (EU) General Food Law (EU, 2002). The ISO(9001: 2000 Quality Management Systems) describes traceability as 'the ability to trace the history, application or location of that which is under consideration. When considering the product (3.4.2), traceability can relate to the origin of materials and part, the processing history, and the distribution and location of the product after delivery"(Aung et al. 2014). The EU General Food Law (Regulation 178/2002) defines as "the ability to trace and follow a food, feed, food-producing animal or substance intended to be, or expected to be incorporated into a food or feed, through all stages of production, processing and distribution". In this study, traceability is defined as the ability to maintain the alignment of information with material flows and transformation from point of production to final retail for the purpose of adding or retaining the value of the product under consideration.

2.3.1 DIMENSIONS OF TRACEABILITY

Traceability can also be examined in relation to at least 7 dimensions covering: product; process; genetic; input; disease/pest; measurement; and, consumption traceability (Opara, 2003; Mirowski & Turner et al. 2014). Product traceability determines the physical location of a product at any stage in the supply chain to facilitate logistics and inventory management, product recall and dissemination of information to consumers and other stakeholders. Process traceability aims to ascertain the type and sequence of activities that have affected the product during the growing and post-harvest operations (what happened, where, and when). Genetic traceability enables the determination of food origin though the analysis of the genetic constitution of the product. Inputs traceability determines the type and origin (source, supplier) of inputs (e.g. fertilizer, chemical sprays, irrigation water, livestock, feed), and the presence of additives and chemicals used for the preservation and/or transformation of the primary raw food material into processed (reconstituted or new) food products. Disease and pest traceability is the ability to trace the epidemiology of pests, and biotic hazards such as bacteria, viruses and other emerging pathogens that may contaminate the food. Measurement traceability traces individual measurement results through an unbroken chain of calibrations to accepted reference standards. A seventh dimension called consumption traceability (Mirowski & Turner et al. 2014) focuses on how aggregated real-time data, including feedback voluntary provided by consumers through their mobile devices about products, is used to generate and deliver value to food producer (Mirowsk & Turner et al. 2014). These seven elements provide food producers with a framework for conducting a whole of chain traceability due diligence in order to identify where precautionary measures are needed to mitigate against food safety and security risks, as well as to identify critical traceability points for optimisation and enhanced productivity.

2.3.1 DIMENSIONS OF TRACEABILITY

AS discussed in the previous section, Opara (2003) and Mirowski & Turner (2014) identified seven important dimensions of traceability that describe areas of risks/opportunities and challenges that may impact the red meat supply chain. They include product, process, input, genetic, disease and pest, measurement, and consumption. In the next section, the discussion of each of these dimensions is presented.

2.3.1.1 PRODUCT TRACEABILITY

Product traceability involves the ability to determine the physical location of a product at any stage in the supply chain in the event of a product recall and dissemination of information to consumers and other stakeholders. Data elements aligned with product traceability include: (1) a reference animal id or product, or reference code which ensures that continual linkage between live animal and carcase; (2) country of birth describes geographical origin where the meat is from; (3) country of fattening describes region of additional feeding (for grain-fed cattle); (4) country of slaughter describes the location where the animal has been slaughtered; (5) and country of cutting indicating region where further aggregation and packaging have been performed (Yordanov et al. 2006).

2.3.1.2 PROCESS TRACEABILITY

Process traceability involves the ability to ascertain type and sequence of activities and processes that have affected the product along the value chain. Important data elements aligned with process traceability include the documentation of physical/mechanical, chemical, environmental & atmospheric variables that contribute to the final production and transformation of product from of raw material into value-added products. Along the red meat supply chain, beef cattle and sheep are exposed to a range of micro-environmental parameter during their lifetime, and these parameters could have a negative impact on safety and quality. **At the farm**, process traceability could relate primarily to understanding the behavioural condition of the cattle as part of understanding how to improve animal welfare and maintain meat quality. Proxy parameters such as measuring activity, lying, and temperature (ALT) of the livestock are acknowledged as opening up new possibilities for early detection of illness or oestrus in beef cattle(Alsaaod et al. 2012; Brehme et al. 2008). **During transport**, capturing vibration levels of a truck and on cattle during road transport has been used to track and trace animal welfare during transport (Honkavaara et al. 2005; Wikner et al. 2003). The thermal humidity index (THI) is an essential parameter for monitoring animal welfare, especially in temperate regions where animals are exposed to heat stress (Dikmen et al. 2009). **At the meat processor**, the sequence of activities includes stunning, deboning, chilling, packaging and storage are routes through which meat could be exposed to risks of contamination or spoilage (Kim & Yim 2016).

Physiochemical and microbiological parameters (e.g. temperature, humidity, and presence of pathogenic materials), are among some of the most common parameters used to validate process traceability along the red meat value chain [12]. These parameters are frequently measured in the cold transport and retail phase of the red meat supply chain where red meat can be exposed to risks during further aggregation or when they are stored over a long period of time in the refrigerating area.

2.3.1.3 GENETIC TRACEABILITY

Genetic traceability determines the genetic constitution of the product, including type and origin (source, supplier) used to create the raw and finished product. In the farm, animal deoxyribonucleic acid (DNA) marker can be used to determine the origin of

[12] https://www.foodstandards.gov.au/publications/Documents/Compedium%20of%20Microbiological%20Criteria/Compendium%20of%20Microbiological%20Criteria.pdf

red meat using blood, hair, or other tissue samples(Stanford et al. 2001). DNA techniques are also used in assessing the origin of feed products used to raise cattle and sheep, and whether such feeds have been genetically modified or not(Mazza et al. 2005).

2.3.1.4 INPUT TRACEABILITY

Inputs traceability determines the type and origin of external inputs, e.g. fertilizer, chemical sprays, irrigation water, livestock, feed, and the presence of additives and chemicals used for the preservation and transformation of the basic raw food material into processed food products. Most common indicators of input traceability relate to labelling accreditations and certifications on the sanitary status of red meat. These certifications include claims such as certified natural beef, source-verified, no-added hormones, no fed antibiotics, grass-fed, no animal proteins in milk (Boland et al. 2007).

2.3.1.5 DISEASE AND PEST TRACEABILITY

Disease and pest traceability involve the ability to traces the epidemiology of pests, and biotic hazards such as bacteria, viruses and other emerging pathogens that may contaminate food and other ingested biological products derived from agricultural raw materials. In Australia, the 'hazard analysis and critical control points' (HACCP) systems are strongly recommended systems in the meat industry to identify and take corrective actions regarding microbiological contamination along the value chain especially in the processing and retail segments[13].

2.3.1.6 MEASUREMENT TRACEABILITY

Measurement traceability involves the ability to validate the accuracy and precision of relates individual measurement results through an unbroken chain of calibrations to accepted reference standards. The goal of measurement traceability is to assure customers of the quality of measurements, i.e. precision and accuracy through the documentation of the calibration procedure in conformance to standard. This standard involves at least 5 major activities, and they include: (a) Definition of quantity to be measured; (b) Complete description of the measurement system used to perform the measurement; (c) Stated measurement result accompanied by a documented uncertainty; (d) Complete specification of the stated reference at the

[13] https://haccp.com.au/

time the measurement system was compared to it; (e) internal measurement assurance program for establishing the status of the measurement system at the time relevant to the claim of traceability; (f) and internal measurement assurance program for determining the status of the stated reference at the time that the measurement was performed[14]. In the red meat industry, one of the widely accepted standards used to ascertain traceability of measurements aligned to the types of equipment and tools utilised in the production of red meat along the chain is the international standard organization (ISO). The ISO has developed a set the requirements for calibration and testing laboratories equipment to a reference standard. The requirements re widely utilised as a quality assurance programs scheme in the red meat industry, for example, in tracing the calibration of sensors and measurement equipment (Nicholas et al. 2002).

2.3.1.7 CONSUMPTION TRACEABILITY

The integration of consumers and their feedback as part of implementing a robust system have been widely discussed in the literature (Gellynck et al. 2001). Mirowski & Turner et al. (2014) defined consumption traceability as a form of traceability that involves how aggregated real-time data, including that feedback voluntarily provided by consumers through their mobile devices about products, can be used to generate and provide value to the supply chain in terms of enhancing production practices and understanding consumer expectation of meat quality. This dimension of traceability can also be related to the democratization of the red meat value chain in which consumers become active participators in red meat production in areas such as ethical meat production and processing, branding and product labelling, consumer food choice tracking, meat safety and recall, meat recipe development**.**

2.3.2 FUNCTIONS OF TRACEABILITY

According to Hobbs (2003), traceability performs three main functions in the supply chain. The first function is to facilitate traceback of product or animals in the event of a food safety problem, known as an ex-post reactive function. In this case, it enables the identification of a source of contamination, thereby minimising private and public costs, e.g. a company’s reputation, consumer illness, or liability cost. The

[14] https://www.calibrate.co.uk/general-calibration/the-importance-of-measurement-standards-and-traceability/

second function of traceability is concerned with the tort liability law. This law refers to minimising civil liabilities by adopting measures to enhance the safety of food products. According to Bessel et al. (2006), parties may be liable in the tort of negligence for failure to meet an adequate standard of care in production and preparation of a product, even if no explicit statutory rules are surrounding the process(Bessel et al. 2006). This function of traceability is called ex-post information and liability function, and this implies that the source of a given hazard will be held responsible for the consequences of its actions (Monjardino de Souza Monteiro et al. 2004). The third function is pre-purchase quality verification, aimed at reducing information cost between consumer and producers through labelling of credence attributes, including those related to food safety, environmentally friendly production practices, animal welfare. According to Hobbs (2003), if consumers value this information, it is anticipated that they will be willing to pay a sufficient premium to offset the additional costs along the supply chain. This function of traceability is called ex-ante information function, which requires proactive information provision and quality verification to consumers.

2.3.3 SCOPE AND IMPLEMENTATION OF TRACEABILITY

Traceability can be implemented at three levels, namely internal, external, and chain traceability. Figure 3: below shows a depiction of the three levels of traceability. It shows that internal traceability involves the tracking and tracing of products within an organisation. In this approach, a business will document activities related to goods reception, processing (any transformation), and dispatch. The sub-activities at the internal traceability could also involve processes mixing, splitting, storage, and destruction. External traceability involves the tracking and tracing of products between organisation. Chain traceability is the integration of internal and external traceability that involves the linking and alignment of information through the means of a recorded identification linked to each actor as meat product is moved from one step of the chain to the other.

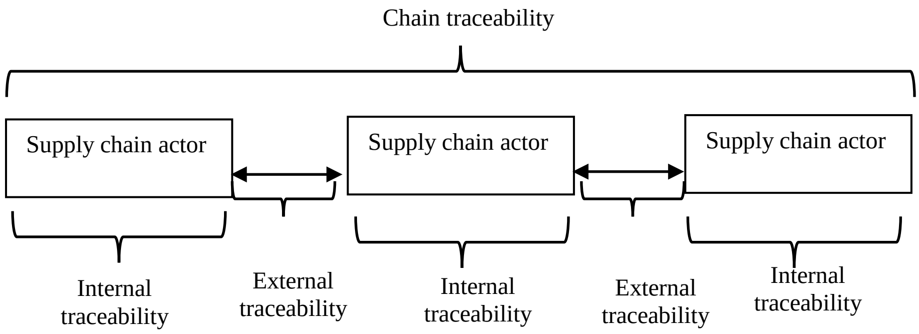

Figure 3: Internal, external and chain traceability (Modified from GSI standard, 2007)

2.3.4 TRACEABILITY APPROACH

Traceability can be implemented in three main approaches, namely: one step up and one step down (OUOD), Chain of Custody (COC) and broadcast delivery/integrated cloud database. Figure 4:- Figure 6 shows the information sharing topology used for traceability across the three main approaches. It shows the OUOD traceability, which is considered the minimum industry standard for traceability in the agro-food supply chain. In OUOD each actor in the supply chain must at least capture and maintain records of (a) incoming shipment from its suppliers; (b) any transformations within its facilities; (c) and to retain outgoing records of shipment information during handover to the next participant along the chain. Most small businesses utilise the OUOD approach because of the limited technological overhead and simple data requirements (Mattevi et al. 2016a).

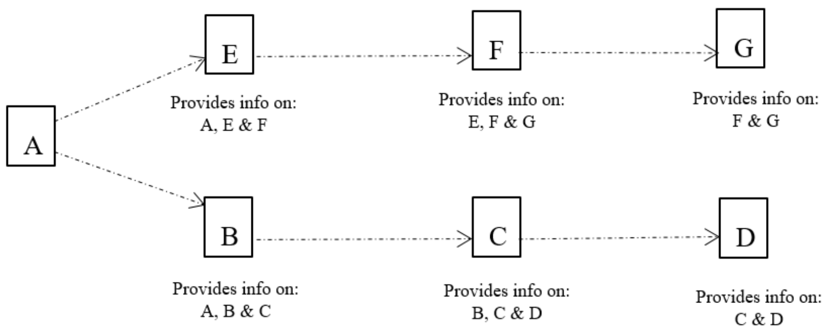

Figure 4: OUOD approach to traceability

The second approach is the pedigree/COC approach, as shown in Figure 5 below. In this approach, traceability is achieved through an incremental capture, documentation and transfer of records related to a product from one actor in a value chain to the other. This requires that each participant document, update, and transfer records of incoming shipment on one original traceability documentation from one step of the chain to the other. This COC approach is widely utilised in various industries, including pharmaceutical, forestry, and fishery, etc., where issues of false declaration of a product are prevalent. The benefit of COC is that only one record is maintained and participants acknowledge the authenticity of the record through a registered signature certifying documentation and transfer from one actor to the other. It is a widely applied traceability approach in highly coordinated and integrated value chains through paper or electronic transfer methods. However, its main drawback is the high documentation overhead in the value chains.

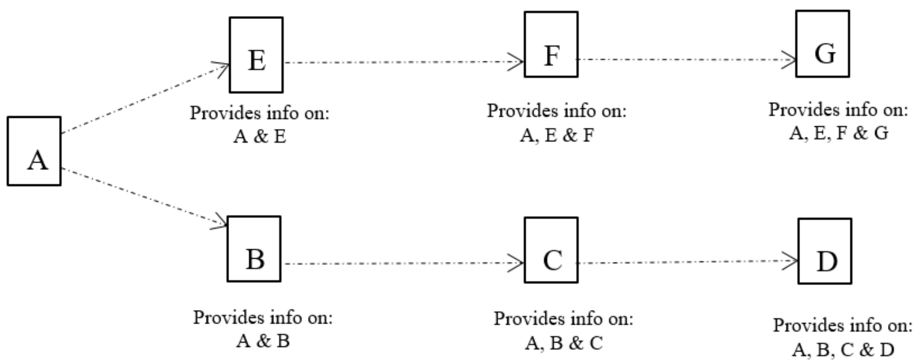

Figure 5: A chain of custody approach to traceability

The third approach is the broadcast delivery approach (Figure 6). In this method, each participant maintains internal custody of records and is connected based on a distributed computing architecture. Information retrieval is achieved through the centralised systems by pulling and pushing data from each participant into its cloud-based server, and at the same time distributing the data to all participant to ensure consistency in traceability records at each step of the chain.

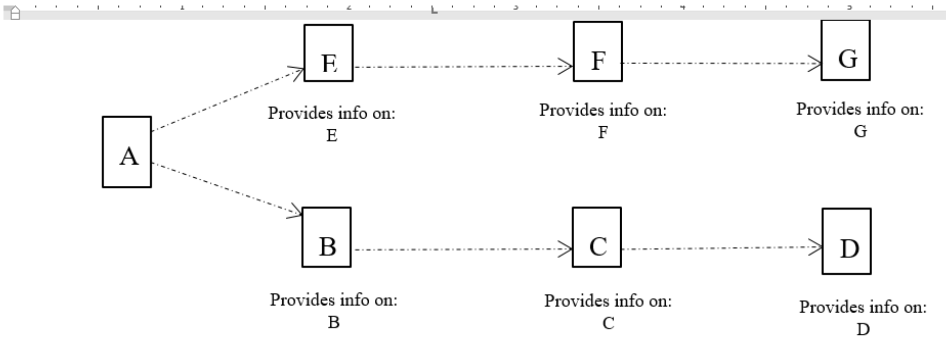

Figure 6: A broadcast delivery approach to traceability

2.4 INFORMATION TECHNOLOGY

IT can be defined as "those technologies engaged in the operation, collection, transport, retrieving, storage, access presentation, and transformation of information in all its forms" (Onn and Sorooshian, 2013 pg. 139). They include systems of information, internet, information and communication-related technologies, and their infrastructure including computer software, networks and hardware, which processes or transmit information to enhance the effectiveness of individuals and organisations. In traceability, several IT tools have been developed and implemented along the red meat supply chain to support traceability. These IT include technologies such as RFID, wireless sensors, mobile application technologies (native and web application), intelligent (packaging) systems, to name a few. Table 1**Error! Reference source not found.** below shows a classification of traceability systems utilised in red meat (beef and lamb) supply chains. It shows the different roles and functions that IT can plays in red meat traceability, across three areas, namely meat verification, identification and linkage and integrated monitoring and control. The role and function describe what the traceability system is capable of performing along the supply chain, e.g. breed verification, identity management, geographical origin verification etc.

Table 1: Classification of red meat traceability system

	Roles and Function	Information	Domain Functionality	Technologies	References
Traceback	Meat verification	Breed, sex, geographical origin, animal type,	Local/ segmented (farm, slaughterhouse)	DNA markers	(Dalvit et al. 2007).
	Identity verification	Animal identification	Local (farm level)	Retina and recognition systems	(Rusk et al. 2006; Allen et al. 2008)
	Identity Verification	Animal identification	Local (farm level)	Nose and facial verification systems	(Awad et al. 2013; Tharwat et al. 2014),
Identification and Linkage (IL)	Beef cattle Identity preservation	Traceable unit –Unique animal ID, Lot/batch ID, Logistic unit,	Farm-slaughterhouse, slaughterhouse to retail, farm-retail.	RFID and EPCIS infrastructure, NFC, Barcode, Data exchange: XML, EDI, Internet Relational Database management systems (RDMS)	(Okabe et al. 2007; Seo et al. 2008; Wallace et al. 2008; Matete et al. 2010; Wang, Fu, et al. 2010; Zong et al. 2010; Feng et al. 2013)
Monitoring and control (MC)	Identity preservation and monitoring	Traceable unit, animal surveillance data	Enterprise/ Multi-site (farm – carcass level), Farm – retail level)	RFID EPCIS, Barcode, Internet, GIS, sensor networks	(DeMarco et al. 2002; González et al. 2008; Kuswandi et al. 2011; Chaurasiya 2012)

The domain describes the scope of application and systems integration that can be achieved using each traceability system functionality, i.e. Local, Connected, Integrated. Local systems operate at restricted sections of the supply chain where data exchange is limited. Connected systems can link each animal to beef cuts along the supply chain and facilitate information exchange. Integrated systems unite a wide range of data and information captured along the supply chain for monitoring and control. It also shows the type of information that can be generated, captured, and manipulated using the level of traceability system functionality, e.g. traceable unit data, processing information, biological data. The technologies section shows the range of tools that can be utilised to support traceability and for responding to some of the critical challenges faced along the chain. For example, in terms of genetic traceability, DNA markers can be used to support of the verification of the genetic origin of livestock. In terms of animal identification, important technologies such as RFID and Barcode technologies is widely utilised to support traceability of red meat along the chain. In the area of identity preservation and monitoring of livestock, an integrated approach involving the use of sensors, database systems and information transmission protocol such as XML have been proposed. The discussion of these technologies and their role and potential in traceability along the red meat supply chain is presented in the next section.

2.4.1 RFID

RFID uses radio frequency signals for automatic identification of objects(Rao et al. 2005) and is widely utilised for the unique identification of cattle. RFID tags employed in the implementation of traceability can be low-frequency passive (13.56 MHz) or high-frequency active tags (915 MHz). Passive tags usually rely on the proximity to an electromagnetic field (also called Near Field) created by RFID reader’s antenna for power and tag interactions. Active RFIG tags usually have embedded battery power and can send encoded signals to nearby antennae over longer range distances and at regular intervals. RFID technologies play essential roles in traceability in areas such as animal identification, identify preservation, property identification, and lifecycle monitoring. A generic RFID system is shown in Figure 7(GS1 Japan, 2011). It consists of RFID tags, centralised database and information transmission system, e.g. electronic data interchange (EDI) and eXtensible Markup Language (XML), and barcode label for individual cuts of meat.

The RFID tags can be implanted into cattle skin (injectable RFID tags) or affixed to the ear of the animal. Information that can be registered to each tag includes data elements such as breed, gender, date of birth, place of birth, transfer records, slaughter locations and date of slaughter and these are linked to a centralised database for exchange or retrieval in the event of an investigation or purpose of verification of compliance. Once an animal has been slaughtered, barcode labelling system is utilised to provide linkage between a carcase and live animal. Two-dimensional barcodes (or tags) can store a limited amount of information which are displayed as machine-readable dots and spaces. The benefit is that it can operate as portable databases when scanned and decoded by camera-equipped mobile phones or mobile scanning devices. Decoding alphanumeric data in 2D codes allow users to access encoded information on meat packages regardless of access to internet connectivity.

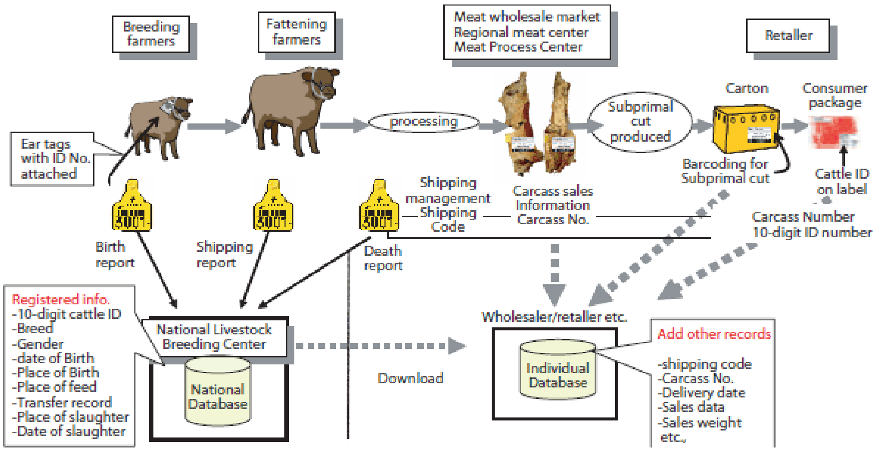

Figure 7: RFID based beef traceability system in Japan based on animal identification and linkage (GS1 Japan, 2011)

Different architectural models for implementing RFID-based traceability systems with barcode functionality have been proposed by several authors (Bao et al. 2011; Feng et al. 2013; Matete et al. 2010; Okabe et al. 2007; Seo et al. 2008; Wallace et al. 2008). Yang et al. (2011) developed a Halal beef quality traceability system by integrating a central information system with RFID, GS1-128 two-dimensional barcode, global system for mobile communication (GSM) technologies, and wireless internet technology. Their infrastructure showed capabilities of linking animal data from the farm and after slaughtering using an integration of EIS technologies to link and share information along the chain. RFID enabled traceability system can be configured to support farm to slaughterhouse or farm to retail traceability depending on the level of integration in the value chain. For example, Velez et al. (2013) proposed a beef farm-post slaughter traceability system capable of linking animal origin to post-slaughter cuts. The proposed solution aims at generating linked labels (such as barcodes) generated from the RFID tags on beef cattle and Bovine Identification Document (BID) passport for each meat pieces resulting from the butchering of the beef. However, this level of precision can be very challenging in value chains that are not properly aligned and integrated. A key issue relates to cost and technical difficulties in integrating the value chain from farm to final retail (Smith et al. (2008).

2.4.2 NFC

Near Field Communication (NFC) is a new short-range, standards-based wireless connectivity technology, that uses magnetic field induction to enable communication between electronic devices nearby[15]. Based on RFID technology, NFC operates in a frequency range centred on 13.56 MHz and offers a data transmission rate of up to 424kbit/s within a distance of approximately 10 centimetres. In contrast to the conventional contactless technology in this frequency range (only active-passive communications), communications between NFC-capable devices can be active-active (peer-to-peer) as well as active-passive(Macias et al. 2014). Most modern mobile devices (e.g. smartphones, tablets and notebooks) are equipped with NFC readers which can perform contactless registration with other NFC enabled tags using inbuilt software or specific mobile applications, e.g. Android(Kowalski 2012). A number of architectural frameworks for implementing NFC based traceability systems have been proposed, such as pork (Pigini et al. 2017), fresh vegetable (Mainetti et al. 2013), and beef (Zhang et al. 2016).

2.4.3 SENSORS

A sensor is defined as a device that converts a physical, chemical, or biological parameter into an electrical signal (Bröring et al. 2011). Sensors are utilised in a wide variety of application in industrial and manufacturing systems and have recently

[15] https://cdn.rohde-schwarz.com/pws/dl_downloads/dl_application/application_notes/1ma182/1MA182_5E_NFC_WHITE_PAPER.pdf

begun to become part of traceability implementation in food supply chains. A typical application of sensors include for measuring temperature (i.e. a thermometer), humidity sensors, wind speed (an anemometer), location (global position systems (GPS) sensors), measuring movement and vibration (accelerometer) sensors (Chaurasiya 2012), biosensors (DeMarco et al. 2002) and more recently for detecting food spoilage (Kuswandi et al. 2011).

In traceability investigations using sensors applications along agri-food supply chains, a wide variety of implementation studies have been conducted(Badia-Melis et al. 2015). For example, Alfian et al. (2017) proposed an e-pedigree food traceability system, utilising radio frequency identification technology to track and trace product location and wireless sensor network to collect temperature and humidity during storage and transportation. More recently, smart sensors system that posses sensing capabilities with embedded intelligence for processing, display and characterisation of data have been recently developed for use in various industrial applications (Hunter et al. 2010).

There has also been the use of smart sensing system in food packaging in what has been described as intelligent packaging systems(Kerry et al. 2006). Intelligent packaging systems can be defined as a packaging system capable of carrying out intelligent functions (such as detecting, sensing, recording, tracking, communicating, and applying scientific logic) to facilitate decision making in terms of shelf life, meat safety, meat quality, provide information, and warn about possible problems (Yam et al. 2005). They can be attached as labels, incorporated into, or printed onto a food packaging material and offer enhanced possibilities to monitor product quality, trace the critical points, and give more detailed information throughout the supply chain(Han et al. 2005). It has also been suggested that intelligent systems can enhance the sensory properties of meat products while maintaining its quality within the packaged food(Biji et al. 2015). The research literature on intelligent smart technologies in the red meat industry has grown rapidly(Pereira de Abreu et al. 2012). Example of intelligent packaging systems includes time-temperature integrators (TTI), leakage indicators, and Luminescence- based indicators have been proposed in implemented in different case studies(Müller et al. 2019). These intelligent systems are also able to ensure traceability along the supply chain through the integration of smart RFID labels embedded within the packages (Otles et al. 2016).

Some recent studies have explored how intelligent packaging systems can be used to monitor food products, provide information about their chemical and microbiological status, as well as indicate quality status during transport, storage and purchase(Mohebi et al. 2015). Recently, some studies using TTI have demonstrated how intelligent packaging systems can become part of traceability and meat safety(Ščetar et al. 2010). For example, Zabala et al. (2015) proposed a novel temperature indicator (TTI) label using a kinetics model that shows the colour of the TTI label along time based on its temperatures conditions. The outcome of this innovative TTI models is its usefulness for providing the time-temperature history of packaged meat and as an indicator of food quality throughout its shelf life. Leakage indicators have also been utilised in the beef industry to validate the integrity of the package during distribution, handling and purchase. Commercially available and patented designs include Ageless eye sensor developed by Mitsubishi Gas company(Won et al. 2016). This can be used to detect oxygen leaks over time in packages during transportation and storage in retail stores.

WSN represents a network of sensors used together for the collection and transmission of different types of information, gathered from the surrounding environment (Costa et al. 2013). In red meat traceability, WSN systems can be used to improve temperature traceability along the cold logistics chain (Carullo et al. 2009; Shan et al. 2004). For example, Thakur et al. (2015) developed an integrated Electronic Product Codes (EPC) based online system for time–temperature monitoring and documenting traceability in a cold meat chain. The system functionality includes an RFID based temperature sensors and a GSM/GPRS based communication system, web-based system for real-time temperature monitoring during transportation.

2.4.3.1 ANIMAL ACTIVITY MONITORING SYSTEM

Sensor-based devices are beginning to play essential roles in traceability for animal welfare. For example, pedometers with capabilities to measure Activity, Lying, and Temperature (ALT) condition of a cattle can be used to assess and respond to illness in cattle and, and also support precise detection of oestrus. These sensors can track the movement of livestock to improve early detection of heat, illness, stress, or abrupt behaviours (González et al. 2008). More advanced sensor technologies have also been utilised to measure vibration levels of trucks and to optimise handling procedures during transportation of cattle and sheep(Aradom 2012). One example is the GEA Cow View system® (GEA Farm Technologies, Bönen, Germany) equipped with behavioural and positioning sensors. (Tullo et al. 2016). The technologies can be used to track animal well being and health status more rapidly to support early detection of illness, lameness or heat. A low-cost alternative called the OviBovi cow monitoring system has been recently developed[16]. The OviBovi system utilises with a microelectromechanical sensor (MEMS) to track the pedometric activity patterns of cows for heat detection, lameness detection, or symptoms of illness. The system is equipped with a web-based dashboard platform and a short messaging service (SMS) alert system which provides current information to the farmer regarding the status of the animal

2.4.4 BLOCKCHAINS

Blockchain is a decentralised, shared, distributed ledger technology that uses cryptography to validate and record transactions and track assets in a business network (Mohan 2018). Blockchain technologies address a central issue of distrust in value chains (Kaye-Blake 2018). The first application of the blockchain technology was Bitcoin, a peer-to-peer electronic cash system that is designed to eliminate dis-intermediation, fraud, and accountability (Tripoli et al. 2018). Blockchain technology has been applied in the implementation of traceability for palm oil(Hirbli 2018). In Australia, a few use cases of the use of block traceability in the red meat industry are being explored by the MLA[17].

2.4.5 MOBILE TECHNOLOGIES

A mobile application mostly referred to as a mobile app, is a type of software application designed to run on mobile devices, such as a smartphone or tablet devices (Zhang et al. 2005). Mobile apps are designed based on the operating system platform of the mobile devices using most common Java and Swift frameworks, i.e. Apple. Two of the most common operating systems frameworks running mobile applications in devices are Android OS and Apple iOS. Android OS is an open-source operating system developed by Google to power a range of devices such as smart televisions, tablets, smartphones. Its' open software platform is currently

[16] https://ovi-bovi.com/en/cow-activity-monitoring.html
[17] https://www.mla.com.au/research-and-development/blockchain/

available to operators, original equipment manufacturers (OEMs) and developers, through which mobile applications can be developed (Silva-Pedroza et al. 2017). iOS is a mobile operating system created and developed by Apple Inc., and is exclusively utilised for its Apple hardware which includes mobile phones, tablets, smartwatch, streaming devices[18]. Apple has designed a programming language, called Swift, upon which mobile applications can be developed to run on iOS platforms. The current version is Swift 4. The use of mobile application technologies in developing traceability systems for beef and lamb has proliferated. The benefit of having a mobile application is the portability and speed of access to information as compared to a traceability system developed for desktop computing systems. Some authors have also proposed different topologies and frameworks for implementing mobile technologies for food traceability(Szilagyi et al. 2006). For example, Luo et al. (2017) proposed a distributed computing approach for implementing a mobile-based traceability application for tracking and tracing food products. Mobile traceability solution has also been used to automatically record the key information regarding agricultural practices in the farm to facilitate transparency and internal traceability(Liu et al. 2016).

2.5 NATIONAL LIVESTOCK IDENTIFICATION SYSTEMS

Australia's system for tracking and tracing of red meat is called the national livestock identification systems (NLIS)(Adam et al. 2016). The NLIS is a partnership between government and industry stakeholders that aimed to develop a nationwide traceability system for meat and livestock from farm to slaughter (Trevarthen 2007). It is a lifetime traceability system, and this means that it is limited to the slaughter phase of the supply chain. The NLIS, introduced in 1999, was developed to achieve four main objectives, namely biosecurity, meat safety, product integrity, and market access (MLA 2016). Since the introduction of NLIS, beef producers in Australia now possess the ability to track the movement and history of cattle from birth to final slaughter (Iglesias et al. 2015). NLIS consists of three components, and they are:(a) unique identification technologies, e.g. ear tags, rumen loses, or injectable transponder; (b) a central data system; (c) and a unique property identification code

[18] https://www.apple.com/au/ios/ios-12/

(PIC). Combined, the NLIS system is able to provide traceability of livestock from farm to slaughter

The implementation of NLIS traceability in the red meat industry is accompanied by several meat accreditation programs at different segment of the red meat supply chain. These include the Livestock Production Assurance (LPA), LPA National Vendor Declaration (LPA NVD), Truck safe, Authority for the Uniform Specification of Meat and Livestock (AUS-MEAT), and Meat Standards Australia (MSA). These programs aim to promote transparency, improve consumer assurance, gain access to overseas market and minimise biosecurity and safety risks in the industry as a whole. LPA is the Australian livestock industry's on-farm assurance program covering food safety, animal welfare and biosecurity. It provides evidence of livestock history and on-farm practices when transferring livestock through the red meat value chain [19]. LPA assessment include: (a) Property risk assessment; (b) Safe and responsible animal treatments; (c) Stock foods, fodder crops, grain and pasture treatments; (d) Preparation for dispatch of livestock; (d) Livestock transactions and movements; (e) Biosecurity; and (f) Animal Welfare. The LPA National Vendor Declaration (LPA NVD) is Australia's waybill declaration documentation that is required for any movement of stock between properties, i.e. sale yards, processors, farms. Truck safe is an audited quality assurance program for livestock transport covering animal welfare, food safety and traceability during road transportation. The issue of Animal Welfare is focused on humane transportation of the stock, and guidelines to prevent disease transmission, stress and contamination during road transport. AUS-MEAT provides a standardised set of objective descriptions for meat and livestock. AUS-MEAT is used by beef producers, abattoirs, wholesalers, retailers and the foodservice industry to provide a uniform description of red meat using a clear and concise set of conventions[20]. Meat Standards Australia (MSA) index on carcasses that meet MSA minimum requirements. MSA was developed by the Australian red meat industry to describe the value of a carcass in clearly defined terms useful to the meat industry and consumers[21].

[19] https://www.mla.com.au/meat-safety-and-traceability/red-meat-integrity-system/about-the-livestock-production-assurance-program/

[20] https://futurebeef.com.au/knowledge-centre/the-aus-meat-language/

[21] http://animalbiosciences.uoguelph.ca/~swatland/HTML10234/LEC28/LEC28.html

2.5.1 TRACEABILITY IN THE TASMANIAN RED MEAT INDUSTRY

In Tasmania, traceability through the NLIS is administered through the Department for Primary Industries, Parks, Water and Environment (DPIPWE). DPIPWE provides local administration and oversight duties of the implementation of mandatory accreditation schemes in traceability along the supply chain value chain[22]. The DPIPWE consists of six organisational divisions, and they include: (a) Biosecurity and Traceability; (b) Product Integrity. (c) Agricultural and Veterinary Chemicals; (d) Animal brands: (e) Animal Welfare: Animal biosecurity and traceability division aims to minimise risks of severe disease in the red meat supply chain through early diagnosis and detection, and corrective action/isolation to prevent possibilities of disease spread. Product integrity division focuses on ensuring that food produced in Tasmania's primary production and processing sectors are safe for consumption in order to protect Tasmania's reputation as a producer of safe and clean food sent to domestic and international markets. Agricultural, veterinary office (AgVet) and chemicals play an essential role in traceability by conducting monitoring programs aimed at preventing veterinary chemical residues from entering the red meat supply. Animal brands ensure that farmers register earmarks, tattoos, and body brands used to identify their cattle or sheep on the farm or during the transfer of ownership[23]. Animal welfare division is focused on enforcing minimal animal welfare standards in the red meat industry and conducts routine inspections on farms where animals are kept for commercial purposes. These six organisational divisions have been established to identify and respond to risks and challenges as well as identify opportunities for improvement along the different segments of the red meat supply chain. In addition to these divisions, the DPIPWE also works closely with local council offices in responding to issues of consumers such as raising public health awareness, food safety recall, and Consumer complaints.

[22] https://dpipwe.tas.gov.au/

[23] https://dpipwe.tas.gov.au/agriculture/animal-industries/identifying-selling-moving-livestock/brands-earmarks-tattoos

2.6 POTENTIAL TRACEABILITY CHALLENGES IN THE RED MEAT INDUSTRY SUPPLY CHAINS

The red meat industry faces significant challenges in their ability respond to changing consumer concerns about product safety and animal welfare and also guaranteeing consistent, high-quality meat in a highly competitive (Rolf et al. 2014; Verbeke et al. 2000). These challenges include growing consumer awareness about the food that they eat, concern about health and nutrition benefit of red meat, issues of food safety, meeting consumer expectation on provenance, and mitigating risks of substitution, mislabelling. These challenges have become some of the key attention points for red meat production in the 21st century. In the red meat industry, traceability challenges are related to four key areas, namely meat provenance(Monahan et al. 2018), meat safety(Aung et al. 2014; Schröder et al. 2002), meat quality/authenticity (Ballin 2010), and animal welfare (Xu et al. 2019). These traceability challenges are widely regarded as the most critical and significant affecting businesses operating in most red meat supply chains (Dabbene et al. 2014; Shackell 2008; Sofos 2008).

2.6.1 MEAT SAFETY

Meat safety has been at the forefront of societal concerns in recent years around the world (Sofos 2008; ZAN et al. 2006). It is estimated that each year in the United States, there are approximately 76 million food-borne illnesses (Zhao et al. 2001). In Australia, more than 4million food safety cases recorded in 2010. These findings suggest that meat safety remains an will continue to be one of the critical area of concern for consumers and industry stakeholders due to changes in animal production, new methods for product processing and distribution (Sofos 2008).

In the last decade, several authors have researched some of the critical meat safety issues facing the red meat industry (Nychas et al. 2008; Saucier 2016). These include cases of spoilage due to microbial contamination and growth of pathogens(Leger et al. 2004); poor hygiene (Ghafir et al. 2008); poor processing conditions(Sumner et al. 2011); inability to support meat recall (Shang et al. 2017); compliance/quality assurance/meat inspection (Butler et al. 2003) and HACCP compliance (Horchner et al. 2006); detection of chemical/antibiotics residue (Alla et al. 2013); and packaging techniques (Sebranek et al. 2006); and shelf life (Emanuel et al. 2020). Other potential challenges related to traceability in the area of meat safety include the inability to ascertain the origin of zoonotic evolving and new pathogenic microorganisms in meat products (Nørrung et al. 2008), and limited capacity to conduct foodborne illness surveillance and food attribution activities (Ghafir et al. 2005). Some studies have raised the issues of chemical residue detection as increasingly significant for the industry in regards to meat safety (Bedale 2019), and the possibility of faecal contamination during processing and packaging (Gaspar et al. 2019).

Among these challenges mentioned, the research literature finds that one of the most severe meat safety issues relates to the possibility of microbial, and especially bacterial pathogens (Sofos 2008). Two most common pathogenic bacterial contaminants in red meats include the *Escherichia* coli and *Salmonella*. Suggested primary sources and routes of meat safety and contamination risks include during slaughter such as hides removal, gastro-intestinal tract, process environment (Bacon 2005).In the post-slaughter area, evidence suggests that meat products are also exposed to contamination risks in areas such as chilling, cutting, deboning, and slicing processes (Kim, Hur, et al. 2018). For most meat products, mitigating risks associated with safety involves the testing and measurement of some physical parameters such as temperature, and microbiological indicators such as total aerobic plate count (APC), coliform count (CC), and Escherichia coli count (ECC). Although both parameters are essential, it widely acknowledged that temperature is the most important influencing factor impacting meat safety and eventual quality (Raab et al. 2011). Thus, maintaining optimal temperature condition along the cold chain is extremely important to ensure the supply of high quality and safe products as well as for the reduction of waste and economic losses(Raab et al. 2011).

Another area that has gathered significant attention in the field of meat safety is the cold chain. It is known that the cold chain represents one of the weakest segment of quality and meat safety assurance systems for most meat products with temperature frequently deviating from specifications established at 5^{o}C or below(Koutsoumanis et al. 2005). Several studies have suggested strategies for optimising cold chain management and distribution of meat products using food safety risk management approaches such as the hazard analysis critical control point (HACCP), International Standard Organisation (ISO) safety and quality assurance system (Zorpas et al. 2010).

2.6.2 MEAT PROVENANCE

The oxford dictionary defines provenance as “the place of origin or earliest known history of something”, “the beginning of something's existence” or “a record of ownership[24]. In the context red meat, provenance relates to the geographical origin, farm production system, and a history of the meat's journey from the farm to the consumer's table (Monahan et al. 2018). Demand for transparency of meat provenance, especially for red meat products have increased rapidly over the years. As a result, provenance meat is now an essential consideration in the production, processing, and marketing of beef in the red meat industry. Many consumers identify with a specific geographical region or attach unique preferences to meat product produced from their locality because of the minimal geographic footprint, the limited number of people handling the meat products, and their low impact of environmental sustainability and climate change (Schlich et al. 2009). This changes in consumer demands can be linked to multiple factors, including the fact that consumer habits are evolving, and trust between consumer and producers have been at a record low in past years. The increasing number of food scandals and events that have taken place in the red meat industry over the last two decades have aggravated the concern held by so many. For example, in Poland, there have been reported cases of smuggling sick cows into the meat chain, and this is feared to be more widespread than previously believed[25]. In 2019 in Brazil, suspected changes in use-by-dates for some products have been reported in the media and have been part of an ongoing criminal investigation [26]. In 2011, a Victorian butcher from Melbourne and former national sausage competition winner was fined $50000 for falsely claiming his meat came from King Island[27]. These incidences suggest the vulnerability of most red meat supply chains for provenance risks as well as their inability to mitigate them due to chain complexity of most multi-echelon, poor visibility, and limited transparency.

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24 https://www.lexico.com/en/definition/provenance

25 https://www.theguardian.com/environment/2019/feb/01/sick-cow-meat-scandal-poland-fears-over-other-slaughterhouses

26 https://www.ft.com/content/9225a0a0-5d2d-11e9-840c-530737425559

27 https://www.heraldsun.com.au/news/law-order/victorian-butcher-snagged-in-false-meat-claim/news-story/dff3ffe4a66bc794e4e9a693410c2751

In this context of the research literature, some of the most critical traceability challenges involving meat provenance are related to the inability to: (a) ascertain meat geographical origin; (b) processes involved in the farm production system; and (c) properly maintain a record of a meat's journey from the farm to the consumer's table(Monahan et al. 2018; Osorio et al. 2011). There have also been other significant contributions concerning issues and challenges of meat provenance in red meat supply chains, including those that pertain to inadequate meat labelling (Pointing et al. 2008; Tonsor et al. 2013); issues of species substitution (Walker et al. 2013); product misdescription (Woolfe et al. 2004); country-of-origin labelling(Verbeke et al. 2009); compliance (Charlebois et al. 2014); and disease outbreak (Scoones et al. 2010). Amongst these issues, labelling is one the most significant challenges facing most red meat supply chain as information provided through labels have the potential to influence consumer purchasing decisions and limit opportunities for marketing and branding amongst meat retailers.

2.6.3 MEAT QUALITY

Meat quality is a generic term used to describe properties and perceptions of meat. In the red meat industry, the quality of meat is determined by appraising several factors including freedom from microbiological hazards (food safety), prevention of animal exploitation (animal welfare), the sensorial appeal of meat, i.e. its taste or eating quality, and perceived healthiness, especially concerning the amount and type of fat(Wood et al. 1999). These factors, combined, provide a holistic approach for conducting an overall assessment of meat quality. This assessment is widely acknowledged to be performed by food experts or consumers. For most consumers, this point of an appraisal is usually conducted at the point of purchase using extrinsic attributes such as colour, fat healthiness and price or after consumption in what can be described as experience attributes with juiciness, tenderness, and the flavour being some of the most desirable.

Meat Standards Australia (MSA) is a voluntary eating quality grading program that engages the entire supply chain to focus on delivering beef and sheep meat that meets consumers' eating quality expectations[28]. In Australia, the Meat Standards Australia (MSA) grading was developed to provide a consistent measure of the beef-

[28] https://www.mla.com.au/globalassets/mla-corporate/prices--markets/documents/soti2018.pdf

eating experience for consumers (Polkinghorne et al. 2008). Rather than utilise objective measurements or trained panel sensory assessment, MSA decided to adopt a more consumer-focused methodology through direct consumer assessment(Watson, Gee, et al. 2008). The goal of MSA was to develop a new set of indicators for describing the consistent beef eating experience to the consumer (Watson, Gee, et al. 2008). Since consumers are the ultimate judges of meat quality and their perception influences their purchase decision, efforts by MSA has been to understand consumer preferences with red meat production practices and to align those preferences with consumer meat quality expectations. Options for ensuring this alignment with MSA have included the use of a consumer or trained taste panels and objective measurements. Although the use of objective measurement has been widely applauded for their quantitative assessment (such as shear force and compression), it has been recognised that they remain a one-sided approach to meat quality and do not provide a holistic and multidimensional method for understanding consumer interests and preferences.

Research from the MLA estimated that an additional $152 million was returned to cattle producers in 2017–18 for cattle that met MSA requirements and company specifications. These indicators are underpinned by five fundamental pillars of meat quality as summarised by Pethick et al. (2011), and they include:

a) They must have a high organoleptic appeal, i.e. be juicy, tender and good in flavour to result in an acceptable level of overall liking (eating quality);
b) Products should be health-enhancing such that they are good sources of lean, high-quality protein and nutrients (fatty acid species, minerals and vitamins) that are consistent with a healthy diet (human health attributes);
c) Production systems must be ethical from animal welfare and environmental aspect (ethical);
d) Products are safe, and there is integrity within supply chains to justify claims relating to quality and health-promoting features (food safety and traceability); and
e) Production systems throughout the supply chain are efficient from a cost of production perspective such that consumers perceive the product as ‘good value for money’ – i.e. quality and price is perceived to match (efficiency).

These parameters are import indicators for developing consumer-focused assessment criteria on meat quality and palatability in a commercial environment(Pethick et al. 2011; Polkinghorne et al. 2010).

Within the literature, the traceability challenges related to meat is discussed from two perspectives, and these are consumer-centric and product-centric. The consumer-centric aspects view traceability challenges of meat quality through the lens of maintaining proper alignment between consumer interests, beliefs and preferences and product quality. Examples of this information include those that pertain to lifestyle (e.g. vegetarianism and organic food), religion (e.g. absence of pork from some diets), or diet and health concerns (e.g. absence of allergens)(Ballin 2010). The product-centric view relates to how intrinsic and extrinsic information can be properly aligned to the product, including how the product has been handled along the chains. The most critical traceability challenges in this view relate to issues of fraud and species determination(Song et al. 2019).

According to Ballin (2010), the issue of fraud covers multiple two critical areas of concern including (a) **meat origin—**sex, meat cuts, breed, feed intake, slaughter age, wild versus farmed meat, organic versus conventional meat, and geographic origin and;(b) **meat substitution—**meat species, fat, and protein; meat processing treatment—irradiation, fresh versus thawed meat and meat preparation; non-meat ingredient addition—additives and water. However, emerging areas of growing importance include issues of meat verification such as the physical and structural quality verification of meat(Biswas et al. 2020), cases of meat adulteration(Mai et al. 2019), religious verification, e.g. Halal accreditation and certification verification (Al-Teinaz et al. 2020; Zulfakar et al. 2019) and Kosher meat verification(Holloway et al. 2019). These challenges also have a direct link to authenticity, product marketing and branding along the red meat supply chain(Teixeira et al. 2019).

2.6.4 ANIMAL WELFARE

The issue of animal welfare has been the subject of concern for most consumers, including government and non-governmental agencies around the world. One of the most pertinent events impacting animal welfare is the transportation, and most cattle experience transportation at least once in their lifetime either to slaughter, auction markets or to other farms (Weeks et al. 2002). In Australia, most cattle are road transported, and this is known to be one of the significant stressors in most animals.

Because these animals are transported in trucks, they are exposed to a range of stimuli's foreign to their natural habitation in the farm and as a result, respond aggressively to their condition thereby leading to damage in body condition and poor meat quality(Huertas et al. 2010). In this context, many studies have reported a link between pre-slaughter cattle management and carcase damage (Adzitey 2011; Warriss et al. 1990). Factors such as loading condition, stocking density, the standard of driving and the overall road condition have been identified as important stressors that should be mitigated because of their impact on animal welfare and eventual meat(Tarrant et al. 1988; Tarrant et al. 1992).

In Australia, the red meat industry also faces particular challenges in assuring high animal welfare standards due to large land areas and stock numbers, climatic extremes and relatively low inputs in terms of manpower and infrastructure(Petherick 2006; Petherick 2005). These factors have been found to contribute to poor animal welfare standards such as nutrition, health, mustering and handling, and transportation (Petherick 2006). As Australian consumers become more aware of these welfare challenges through various media sources and advocacy campaigns, concerns over assuring consumers that meat products are produced under humane and acceptable environmental conditions become very necessary. These factors could also play important roles in affecting consumer buying behaviours overtime.

In the last decade, multiple research studies have explored and identified some of the most critical challenges related to animal welfare, and they include poor transportation and handling(Castro et al. 2019); improper management of lairage conditions(Costa et al. 2019; Rudra et al. 2019); longer transportation time (Mendonça et al. 2019); animal stress(Carrasco-García et al. 2020). Closely aligned with these issues include inadequate training and knowledge of abattoir stakeholders (Descovich et al. 2019) and incidents of bruising of the carcase (Bethancourt-Garcia et al. 2019). With increasing attention to climate change and global effect on livestock, an emerging area of concern involves areas of (a) sustainability of red meat production (Henchion et al. 2017; Van Loo et al. 2014); (b) developing environmental friendly production systems(Smith et al. 2018); (c) measuring the carbon footprint of red meat production systems (Edwards-Jones et al. 2009); (e) reducing food miles(Saunders et al. 2008), and (f) greenhouse gas emission (Avery et al. 2008).

2.7 SMALL BUSINESSES

The definition and classification of businesses as small businesses is still a subject of much debate in the research literature (Filion 1990). The Australian Bureau of Statistics (ABS) definition of small businesses is those employing fewer than 20 people[29]. In categorising small businesses under the ABS definition, the following classification emerges, namely: (A) non-employing businesses (sole proprietorships and partnerships without employees); (B) micro-businesses (businesses employing between 1 and 4 people including non-employing businesses); and (C)other small businesses (businesses that employ between 5 and 19 employees).

However, with specific applications in the agro-food industry, it has also been argued that the size-based definition is insufficient for classifying enterprises because large-scale agribusiness operation can be conducted with relatively few or no permanent employees (Uddin et al. 2011). As a result, a more pragmatic definition of small businesses has been suggested based on the estimated value of the agricultural operation (EVAO). Using EVAO definition, a small business is any firm with an estimated value of between $22,500 - $400,000 (ABS 2002)[30].

2.7.1 SMALL BUSINESSES IN THE RED MEAT INDUSTRY

Small businesses are an essential business sector of the Tasmanian red meat industry[31]. They play essential roles from sourcing and supply of raw materials to processing and final food production in the many developed and developing counties (Michelberger 2016). In Australia, small and medium-sized enterprises (SMEs) employ over 40 per cent of Australia's workforce, account for 33 per cent of the nation's GDP, and pay around 12 per cent of total company tax revenue[32] . In the red meat industry, more than 90% of active business are classified as SMEs. These facts reveal the importance of this business sector to the growth and sustainability of Australia's agri-food economy.

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[29] https://www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/pubs/rp/rp1819/SmallBusinessSector#_Toc527009244

[30] https://www.abs.gov.au/ausstats/abs@.nsf/mf/1321.0

[31] https://www.stategrowth.tas.gov.au/business/sectors/food_and_agriculture/food_and_agribusiness

[32] https://www.asbfeo.gov.au/sites/default/files/Small_Business_Statistical_Report-Final.pdf

2.7.2 BARRIERS TO IT IN SMALL BUSINESS

Small businesses face multiple barriers that impact their ability to implement and utilize IT to support organisational operations(Arendt, 2008). Conceptually, these barriers can be discussed at two levels, namely *socio-economic and technological*.

At the socio-economic level, critical external factors such as cost of implementation, nature of businesses, employment status, management decision, organisational objectives, have been widely recorded as being significant issues facing small business ability to support traceability both within individual firms and also along the supply chain (Duxbury et al., 2002). In the study conducted by Burgess (2002) concerning factors that impact small businesses decisions to implement IT, the authors found most typically do not invest in IT because of the: (a) perceived cost of IT implementation; (b) lack of time to devote to the implementation and maintenance of IT; (c) lack of IT knowledge combined with the difficulty in finding useful, impartial advice;(d) lack of use of external consultants and vendors; (e) short-range management perspectives; and (e) lack of understanding of the benefits that IT can provide, and how to measure those benefits. In the red meat industry, a survey conducted by Sharma et al. (2019) with Irish beef cattle farmers, revealed a strong relationship between employment status and technology use and adoption amongst farmers. The authors in their survey found that part-time farmers are less likely to adapt to new technology because they earn less from farming and are not sure about its return of investment. Harker and Anderson (2002) also identified 7 factors which influence IT adoption in SMEs, and these include organisational IT readiness; external pressure to adopt, customer/supplier dependency, structural sophistication of readiness, size, sector, and status and its information intensity. The authors also found that small businesses exhibit a lack of awareness and understanding of the IT, lack of confidence and trust in new technologies, limited managerial capacity. Taylor and Murphy (2004) found in their study that most small businesses do not use IT because their businesses are often locally inclined, prefer to have direct interaction with customers, and are limited to specific consumer markets, i.e. niche markets. The authors concluded that these factors contribute to slow IT adoption due to the perceived lack of need for innovation.

At the technological level, Duxbury et al. (2002) identified several reasons why small businesses fail to implement and utilize IT in their operations. Some of the reasons given for this lack of IT use in their businesses were that : (a) most small businesses lack the adequate technical expertise (Barry & Milner 2002); (b) most lack adequate capital to undertake technological enhancements (Raymond, 2001); (c) most SMEs suffer from inadequate organisational planning (Tetteh & Burn 2001, Miller & Besser 2000); (d) and differ from their larger counterparts in the extent of the product/service range available to the customer. In Tasmanian, the issue of internet connectivity and penetration in many rural areas of Tasmania has been the subject of much concern for many decades. A study conducted by Tasmania's Department of Premier and Cabinet (DPAC) found that Tasmania's digital inclusion index remains very low as compared to other states in Australia (DPAC,2007 pp. 74)[33]. In 2018, a statistical study which computes digital inclusion for all states in Australia known as the Australian digital inclusion index (ADII), ranked Tasmania amongst the second-lowest of any state or territory in Australia besides South Australia with an ADII score at 58.1. However, recent reports have suggested improvement since the roll-out of the national broadband network in many parts of the state[34].

The issue of ICT literacy has been found to significantly impact IT use and adoption amongst many small businesses (Harindranath et al. 2008). ICT literacy focuses on the ability to gather, organize, analyse, and report information using basic IT tools and systems(Leu Jr et al. 2000). A study conducted by the Australian Communications and Media Authority (ACMA) showed that many small businesses are choosing to be late adopters of digital communications technology due to their limited understanding of the benefits and application of ICT in their businesses (ACMA,2014)[35].

2.7.2.1 BARRIERS TO IT TRACEABILITY IN SMALL BUSINESS

Several authors have explored important IT inhibitors that impact the capacity for traceability amongst small businesses in their supply chains (Bosona et al. 2013; Hardt et al. 2017; Xue et al. 2007; Zhang et al. 2011). Conceptually, these barriers can be categorised more broadly into four levels, namely: *organisational, supply*

[33] http://www.dpac.tas.gov.au/__data/assets/word_doc/0006/109941/Appendix_1_-_Data.doc

[34] http://theconversation.com/digital-inclusion-in-tasmania-has-improved-in-line-with-nbn-rollout-will-the-other-states-follow-102257

[35] https://www.acma.gov.au/-/media/Regulatory-Frameworks-and-International-Engagement/Information/pdf/SMEs-and-digital-communications-technologies-pdf.pdf?la=en

chain, individual, and socio-economic. **At the organisational level,** Stockdale (2003), the authors listed some critical barriers impacting the limited role of IT on traceability amongst small businesses. These include: (a) lack of awareness of and education on the need for traceability technology, especially at the full-chain level; (b) Knowledge gaps of what full-chain traceability is and what full-chain digital traceability does; (c) Poorly demonstrated incentives for creating buy-in to the value full-chain digital traceability can offer; (d) Resource deficiencies, including funding and capacity issues; (e) Technical issues with information technology (IT) systems and data management; (f) Logistical hurdles in the operation of traceability systems; and (g) Scaling issues in promoting and achieving broader adoption. However, these barriers are also underpinned by the structure of the supply chain, supply chain relationship amongst actors, and position of the company in the supply chain.

In this context, Manos et al. (2010) explored potential barriers to the implementation of IT traceability amongst small businesses in fresh produce supply chains from the **external and supply chain level**. The authors found that tight profit margins and inadequate knowledge of the potential benefits of traceability systems are some of the main factors that hinder investments in sophisticated traceability schemes along the food chain. The authors also mentioned that underpinning factors associated with these barriers including (a) severe inequities between supply chain actors;(b) current technological and operation status of firms; (c) and availability of firms to undertake the cost of investments in new IT systems along the chain.

In terms of individual perceptions and beliefs, Aris et al. (2014) investigated traceability and recall plans amongst small business owners as operating in Malaysia's food processing sector and found a strong relationship between negative perception and low IT utilisation in traceability, and these include: (a) the negative perception of time, i.e. traceability practices can be time-consuming; (b) limited or no perceivable benefits to the company's Bottomline; (c) and the perceived lack of clear policy guidance and support from the government. Another study conduct by Mattevi and Jones (2016), identified significant organisational barriers influencing IT implementation in traceability amongst small businesses owners. The authors investigated into traceability amongst 164 SMEs in the UK food sector and found that while some SMEs appear to have only moderate awareness and understanding of traceability, others were found to have limited understanding of the potential benefits of enhancing traceability using new IT innovations in their supply chains. The authors also found that, for most businesses, the incentive to implement traceability is more aligned to meeting compliance rather than enhancing information and material flow as part of a supply chain management strategy geared towards improving product quality or meet changing consumer requirements. These findings are similar to those reported by Salin et al. (2000). In the author's study, they found that amongst local farmers, many still lack adequate systems for records management and internal traceability at the individual animal level due to negative perception and lack of willingness to embrace new technologies.

At the socio-economic level, a study conducted by the Australian Department of Industry & Science on small businesses challenges in the red meat supply chain also reveals pertinent issues of concern amongst small businesses[36]. Firstly, the study found that Australian small businesses lack skill shortage in a variety of filed including finance and management, farm and agronomy skills, mechanical skills and sales and marketing skills and as a result are unable to leverage on new technologies to improve productivity. Secondly, the authors mentioned that small businesses still suffer from limited access to capital, higher operating costs, inability to respond to changing market and economic conditions, and the issue of input availability, i.e. availability of stocks. Thirdly, it was stated small businesses lack adequate co-ordination of information and material flows, and this is due in part to poor information sharing, lack of collaboration on joint efforts to optimise product quality performance, the issue of fragmentation. Amongst these issues, fragmentation of the chain was observed to be prevalent at two segments, particularly between the producers (i.e. farm to the processor) and processors segments (processor to retail). This fragmentation was also found to be influencing limited communication, lack of feedback on consumer and processor preferences, and inability to engage with other actors on joint collaborative research to understand and develop new products that meet changing consumer demands and new market preferences.

[36] http://limestonecoastredmeat.com.au/wp-content/uploads/2015/11/AusIndustry-mapping-report-public-version.pdf

2.8 PREVIOUS RELATED STUDIES FOR MITIGATING TRACEABILITY CHALLENGES

Within the research literature, approaches for mitigating traceability risks and challenges amongst small businesses in the red meat supply chain can be grouped into three (3) key areas namely technocentric, consumer-centric, and industry/policy-centric perspectives. Firstly, the technocentric studies explore the role of information technologies for mitigating traceability challenges along the red meat supply chain. Approaches have included the use of RFID, Barcode, DNA fingerprinting, Blockchains, and mobile technologies. For example, DNA-based traceability techniques using single nucleotide polymorphic (SNP) loci obtained from meat and blood samples can be used to facilitate seamless provenance along the red meat supply chain (Dalvit et al. 2007). Other authors have explored the feasibility and practicality of RFID systems for implementing end-to-end traceability in the red meat supply chain (Thakur et al. 2015). Feng et al. (2013) showed how RFID technology with a personal digital assistant (PDA) and barcode printer could be used to support information tracking and tracing across the cattle/beef supply chain. There have also been studies that have utilised new technologies such as near-infrared spectra for the rapid and effective development for lamb meat origin traceability (Sun et al. 2011). However, there are also a number of key barriers including difficulty in supporting automated information collection and management, inefficiencies with communication mechanism associated with an RFID reader, and the potentially high cost of system implementation(Thakur et al. 2015).

Secondly, the consumer-centric studies on information aligned to meat products can be used to enhance consumer engagement, understanding consumer behaviours and attitudes, and stimulate their willingness to pay for more information on red meat purchased (Gracia et al. 2005). These consumer-centric studies focus on key areas: such as (a) consumer willingness to pay for more information (Kehagia, Linardakis, et al. 2007); (b) extent to which consumers are responsive to information cues including those that relate to product-specific (credence versus experience and search attributes, branded versus commodity meat, being exporter); and (c) food assurance and certification (Bulut et al. 2007). Among these studies, one area of increased attention involves exploring how information on meat labels can be repurposed and utilised as an instrument for consumers to facilitate the verification of quality. For example, Stranieri et al. (2009) investigated and evaluated those type of specific meat quality information aligned that can be used to influence consumer interest. Using a survey of 1,025 beef consumers in Italy, the authors found that most consumers tend to use the meat label to inform their purchasing decisions. The critical information cues include country of animal origin, the system of cattle breeding and cattle feeding. A similar study conducted by du Plessis et al. (2012) on lamb meat consumer showed that the most significant information cue influencing consumer purchasing decisions process in the store is the method of raising and rearing the animal. In China, Xu et al. (2019) sampled 316 consumers in Wuxi, located in Jiangsu Province, to examine the impact of various factors (e.g. traceability, lean meat essence testing, animal welfare, appearance, and price) on consumers' preference and willingness to pay (WTP) for pork products. Using a real choice experiment (RCE), the authors ranked the three most important information cues that influences consumer willingness to pay (WTP) for traceability. They found that having a traceable code is the second important factor after price for consumers, and this is followed by a colour (bright red appearance), national stocking density standard of animal welfare, and leanness of the meat.

Thirdly, the industry/stakeholder studies explore traceability system implementation from the perspective of business owners, suppliers, retailers, and third-party actors engaged in the red meat supply chain. For example, Cho et al. (2019) exploring latent factors influencing the adoption and diffusion of an electronic food traceability system (FTS) in South Korea. The researchers utilised the technology acceptance model (TAM) and structural equation modelling (SEM) to guide their investigation. The authors found that contrary to the findings of previous studies, organizational adaptability does not influence a positive effect on attitudes toward traceability system and that business differed in their understanding of the role and impact of FTS in their business. Manning et al. (2015) also explored how IT and traceability can impact small and medium-sized rural food retailers in the red meat industry. Using qualitative interviews with industry insiders and analysis of data from rural food retail stores (n = 20), the authors found that traceability can assist small business retailers in terms of product differentiation through Protected Geographical Indication (PGI), but also provide opportunities to mitigate risks of food fraud/substitution.

2.8.1 MODELS AND FRAMEWORKS FOR IMPLEMENTING TRACEABILITY AND MITIGATING TRACEABILITY CHALLENGES

The disparities in technological requirement among stakeholders in addition to different performance objectives along the chain mean that implementing traceability across a fragmented chain can be challenging. This is because effective traceability systems can only be developed through negotiated conditions among stakeholders in the chain (Matete et al. 2010). Traceability systems in the red meat supply chain should not only perform track and trace objectives but should be linked other performance goals such as effective safety and control system, supply-side and demand-side management, risk mitigation etc. (Golan et al. 2004). By defining stakeholder chain requirements across the cross-functional segment of the food chain, a common understanding for standardisation of the data that enable storing and communication of the data along the chain can be achieved (Matete et al. 2010). This standardization of systems along the chain will allow for the development of a more performance/goal-oriented system and can deliver benefits to all stakeholder. However, amongst small businesses, standardisation of system remains a very challenging task due to issues of fragmentation as discusses earlier. In response to these challenges, the use of a reference (information) model and framework approach has been proposed(Fettke and Loos 2003). Reference information models are information models developed to facilitate the information exchange process between chain organisations, and it provides a reference for the development of best practice solutions within specific projects (Becker et al. 2007). It is a conceptual approach for developing specific models that can be applied to represent categories of applications within specific domains, and it can be adapted for re-use in other similar contexts (Thomas 2005). The literature on reference models reveals a broad range of examples (Fettke & Loos, 2003; Kirchmer, 2010). They include: Industry reference models (representing the best practices of a specific industry sector); Software reference models (these can be traditional applications such as ERP systems or a reference model representing a sub-process supported by service-oriented architecture (SOA); Procedural reference models (e.g., a project management reference model); and Company reference models (representing best practices within a company or a company group).

In the agro-food industry, reference models have been found to be a reliable technique for designing food traceability systems(Van Dorp 2003). It is widely used for developing best practice solutions for tracking and tracing of food most agro-food industry supply chains (Ramesh and Jarke 2001, Küster, Koehler et al. 2006). Reference models can lead to a considerable increase in efficiency in most fragmented food supply chains (Van Dorp 2003). Despite these significant benefits of using reference models and framework approach, till date, the research literature confirms that a sound common theoretical framework for implementing traceability in most food supply chains is yet to emerge (Karlsen et al. 2013). One widely cited approach is the generic framework for food traceability, based on key data elements

(KDEs) and critical tracking events (CTEs) approach proposed by Zhang et al. (2014). The KDE-CTE framework offers recommended guidelines for good traceability practice in the agro-food industry. CTEs are the various points in a supply chain at which data capture is necessary to follow product movement, shipping, receiving, product transformation and depletion along the chain. KDE refers to information that should be captured at each CTE covering product identification, lot, batch, or serial number combination with date, time, and location. The CTE is used to trace events aligned to the movement and transformation of a product shipment across the supply chain. However, the framework does assume that all partners agree to certain information and data capture, which provides harmonisation of traceability.

Another framework that offers generic, well-documented guidelines for good traceability practice in the agro-food industry is the TraceFood framework (Eskil Foras 2007). The main objective of the TraceFood Framework is to support a fully electronic-based traceability system along the food supply chain. It focuses on encouraging information sharing, standardisation of communication between computers through the proposed TraceCore XML. The TraceCore XML contains specifications for how traceability information can be coded, transmitted or made accessible in standardised electronic format, called XML (eXtensible Markup Language). A generic information model for developing a traceability solution based on their framework is also made available for adaptation online (TraceFood 2009). However, this framework strongly advocates the integration of partners in the supply chain through technologies. Thus, the application of this framework faces significant barriers in non-vertically integrated chains, especially amongst small businesses where fragmentation is evident and businesses are individually owned and managed with differences in technologies and information needs.

A similar framework proposed for developing traceability systems in the agro-food industry is the FoodPrint framework (Smith et al. 2006). The FoodPrint framework offers a methodology for designing a traceability system by distinguishing four critical levels of traceability needs, namely: organisation, process, information, and technology. Firstly, at the organisation level, the framework includes the description of the part of the chain covered by traceability system. The framework includes allocations to roles, responsibilities, and liabilities and cost benefits of implementing the traceability system. Secondly, at the process level, the framework suggests a description of the production process across the various steps of the chain, including the documentation of product flows and control processes. Thirdly, at the information level, the framework suggests the development of traceability information model, which can be sector-specific or generic. The model defines the structure of the information to be collected, information entities and their linkage to each traceability goals of the participants involved in the chain. The technological aspects of the framework entail defining the form of tag types, readers, coding to be utilised for identification and product linkage. Consequently, the FoodPrint framework is a methodological approach that aims to align business goals with traceability requirements. However, it does specify how it can be applied to small businesses in fragmented supply chains. The framework does assume that al actors can collaborate on joint information sharing to support traceability.

Regattieri et al. (2007) proposed a generic framework for developing a food traceability system based on fundamental 4 pillars, namely: product identification, data to trace, product routing, and traceability tools. Firstly, product identification involves the capture of unique physical characteristics, such as volume, weight, dimensions, and packaging. It also includes other classes of information dealing with mechanical properties (shortness, condition of surfaces) and length of the life cycle. Secondly, data to trace includes the type and characteristics of the information that a traceability system must manage, for example, related to kind (digits, strings, ranges) and number, or the confidentiality levels. Thirdly, product routing involves recording the product life along the chain and associated processes through various activities such as production, movement, and storage. Finally, traceability tool is concerned with technical solutions needed in the design, development and implementation of traceability systems such as alphanumeric code, barcode, and RFID. Other general frameworks available within literature include those focused on generic data models (Bechini et al. 2005). While this framework is useful for developing traceability, a methodological approach for understanding how it can be implemented with criteria for technology selection and evaluation remains unclear. These reference model usually follow three core requirements: modelling of the bill of lots/batches, modelling of actual operations and variables, and modelling the integration of bills and operations. This generic model covers fundamental traceability requirements for defining the relevant data entity types and relationship types concerning the item produced, the production order responsible, the material lot obtained, the history on constituent material parts, the data of processing and the capacity units processed on. According to the author, the reference data model can be used in blueprinting information systems for tracking and tracing.

However, while these reference framework and models have been utilised in a more integrated supply chain, very limited studies have adapted them for small businesses operating in fragmented red meat supply chains. Also, these models have not provided a structured approach for understanding how IT can be most effectively deployed and evaluated amongst small businesses operating in red meat supply chains to support traceability and mitigate risks.

2.8.2 INFORMATION QUALITY METRICS APPROACH

The use of a structured metric-based approach based on the assessment of information quality parameters for understanding how to enhance traceability and for mitigating risks along the supply chain has emerged as an area of increased importance within the research literature (Zhou 2009). Al-Mamary et al. (2014) define IQ as the quality of information system outputs, which can be described in terms of information outputs that are: (a) useful for business users, relevant for decision making, and easy-to-understand (representing IS quality as value); and (b) meet users' information specifications (representing IS quality as conformance to specification). Wang et al. (1998) defined IQ across four dimensions: intrinsic IQ, contextual IQ, representational IQ, and accessibility IQ. Intrinsic IQ implies that information has quality in its own right, i.e. Accuracy, Objectivity, Believability, Reputation. Contextual IQ highlights the requirement that IQ must be considered within the context of the task at hand in terms of Relevancy, Value-added, Timeliness, Completeness, Amount of data. Representational IQ emphasises the need for a system to present information in such a way that it is Interoperable, easy to understand, concise, consistent; also, and the system must be accessible but secure.

According to Golan et al., (2004), traceability can be assessed in terms 'breadth', 'depth' and 'precision'. The breadth relates to the amount of information recorded by the traceability standard. The depth of the system refers to the distance the system is able to trace, i.e. the identification of the sectors which are involved in the traceability system. The system precision is associated with the degree of assurance with which the system can pinpoint a particular product's movement or characteristics (Bosona and Gebresenbet, 2013; Ruiz-Garcia et al., 2010). McEntire et al. (2010) introduced the fourth criteria called 'access'. The access refers to the speed with which traced information can be communicated to supply chain members and public health institutions during food emergencies.

Molnár et al. (2011) suggested a heuristics transparency framework using information quality metrics. The framework which is shown in figure 8 below consist of four key traceability/transparency domains in a hierarchical order: food quality, food safety, food origin, and food sustainability through visibility assessment have recently emerged (Somapa et al. 2018). The domain of food safety includes three sub-domains representing compositional, technological and organizational issues. The second domain, food quality, can be divided into eight sub-domains: (1) composition, (2) health and nutrition claims, (3) sensory properties, (4) raw material production, (5) storage conditions, (6) processing methods, (7) packaging and distribution and (8) authenticity.

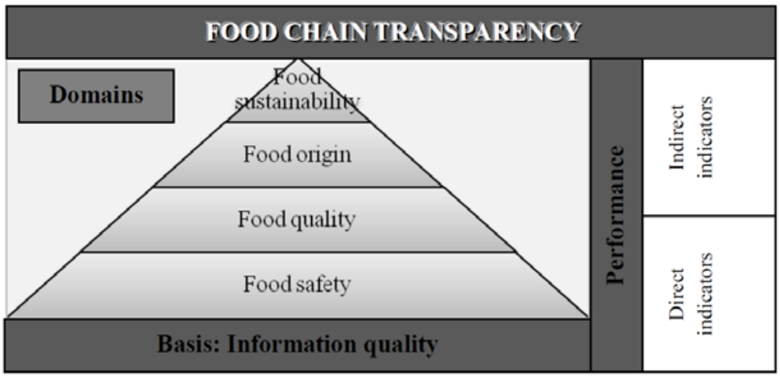


Figure 8: A Theoretical framework for food transparency(Molnár et al. 2011)

The domain of food origin includes aspects of geographical traceability. The domain of food sustainability consists of environmental, social and economic aspects. Underpinning these domains are information quality criteria. The information quality metrics include accuracy, relevance, timeliness, reliability, completeness, usefulness, credibility, trustworthiness, and being up to date. The only drawback with the application of the framework is that the authors did not provide a structured methodology for exploring the challenges and for implementing IT along the supply chain.

Caridi et al. (2010) suggested a structured metric approach that can be used to explore traceability and information quality along supply chains. The assessment framework measures visibility as a way on enhancing traceability in terms of the amount and quality of information that is generated and available along the chain using three information metrics, *namely accessibility, accuracy and freshness and currency*.

In this framework, supply chain visibility is determined by the amount and quality of information that an organisation can readily access and views at each node along the supply chain. The heuristic framework uses three information quality metrics: (a) Freshness: the degree of information "synchronisation" with business partners; (b) Accuracy: the degree of conformity of the shared information with its actual value; (c) Completeness: the degree of completeness of shared information. From among 22 metrics identified in a review of literature on evaluating information quality status in organisations, e.g. assessment methods for information quality (AIMQ) criteria (Naumann and Rolker 2005), the three metrics adopted were found to be the most significant in terms of measuring visibility in multi-tiered supply chains (Caridi et al. 2013). Based on these metrics, it is possible to evaluate supply chain visibility as being the sum of visibility of information that any specific company has access to and views at different nodes/segments in a supply chain. In conducting the field studies this research has used four types of traceability information flows to focus on across the different segments of the beef chain. The four types of traceability information are s=safety, q=quality, p=provenance and w=animal welfare. These four traceability information are indicative of the major risks factors impacting beef supply chains at different segments(Shackell 2008). Therefore in evaluating traceability information flows ="t" the approach is to use the formula t=(s,q,p,w).

This self-assessment approach provides quantitative data on comparative judgements on information quality status in organisations and along the supply chain because it takes into consideration the perspective of information sources, information users, and their information query processes (Naumann and Rolker 2005). This framework also allows for consideration of critical points where IT can be deployed most effectively using IT. Based on the framework, the authors were able to show how the impact of visibility improvement can be evaluated along the supply chain using mathematical formulae. The research has adopted the framework for exploring traceability among small businesses in red meat supply chains. The details of the adapted framework are described in the methodology chapter (Chapter 3). In the next section, the research presents a review of literature on supply chain mapping techniques, which can be used to explore traceability in information and material flow along food supply chains.

2.9 THEORETICAL UNDERPINNINGS ON FOOD TRACEABILITY

Information systems (IS) researchers have a long tradition of drawing on theories from disciplines such as economics, computer science, psychology, and general management and using them in their own research (Wade et al. 2004). Because of this, the information systems field has become rich in theoretical and conceptual foundations (Wade et al. 2004). In the area of food traceability, 2 significant categories of theoretical underpinnings have been suggested and utilised for exploring issues related to food supply chains, and these include the *production economics-based theory* and the *process-based theory*. The *production economics-based theory* these involve 3 main views, namely: Resource-Based View (RBV) theory(Miller 2019), Principal-Agent (PA) theory(Yao et al. 2020), and Transactional Cost Economics (TCE) Theory (Ahluwalia et al. 2020). The second category is the process-oriented approach (Jansen-Vullers et al. 2003), and this is primarily aligned with utilising supply chain metrics such as information quality, e.g. breadth, depth, precision, and access (Smith et al. 2005), for exploring issues and challenges related to traceability in food supply chains.

The RBV paradigm views food traceability systems as unique resources embedded in firms' routines, and posts that IT impact in traceability can be evaluated in terms of the extent to which the technology supports firms' sustainable performance(Faisal et al. 2016). In this stream, firms gain new capabilities by implementing new traceability systems as a value add investment and this that can result in result in competitive advantage if the system utilised can be considered rare, costly to imitate and with limited transferability (Miller 2019). Pels et al. (2009), for example, used the RBV to explore the relationships between food product traceability system based on IT and supply network integration. Their study suggests that developing and implementing food traceability systems is impacted by multiple factors including (a) the technical aspect of supply chain integration; (b) level of organisational knowledge; and (c) extent to which the supply chain is integrated. In another study (Epelbaum et al. 2014), the Resource-Based View (RBV) has been used to determine the strategic impacts of the technological evolution of food traceability systems on firms capability. The authors contributed to the theoretical understanding of food traceability systems in two ways. Firstly, they showed that food traceability systems could be understood as an orchestration of physical resources that can be found in abundant supply but become unique as they are embedded in internal routines and used by firms' human resources. Secondly, the authors also validated the idea that suggests a strong relationship between the implementation of technological innovations and firms' sustainable performance. In their study, they found that as food traceability systems evolve overtime and firms incorporate new technologies, they become a source of sustainable competitive advantage that would be hard for other competitors to replicate.

The TCE paradigm posits that technical change to traceability in food supply chains results in positive impacts in the area of decrease in transaction costs (Buhr 2003).In this paradigm, Hobbs (1996) separates transaction costs into three components: (a) information costs that are related to information about products, prices, inputs and buyers and sellers; (b) negotiation costs that arise from the physical act of the transaction especially in the writing of contracts; and (c) and monitoring costs that emanate after an exchange in terms of the extent to which IT can create greater incentives for vertical ownership, facilitate improved contracting relationships, or even favour open markets if relevant information is readily available to all buyers and sellers. This theoretical underpinning is widely utilised in literature for understanding the potential impacts of IT on traceability(Banterle et al. 2006b; Csaba et al. 2008; Stranieri et al. 2017). In another study conducted by Banterle et al. (2006a), the authors developed a theoretical framework based on TCE to assess whether implementing good traceability increases the degree of vertical coordination and changes in the level of the transaction key features (i.e. the degree of asset specificity, uncertainty and frequency of transactions) in food supply chains. Firstly, the authors' results show that enhanced traceability can lead to increased bilateral dependency among the economic agents and this can be attributed to the rise in human, physical and site assets.

Secondly, the authors also found that enhanced traceability can lead to growth in the frequency and quantity of information exchanged. Thirdly, the authors also found that for medium-sized firms, economic incentives aligned with food traceability play an essential role in guaranteeing the safeguarding of transactions, as compared to big firms that choose to adopt contractual supports in their traceability implementation. Another interested conducted by (Stranieri et al. 2017) utilised TCE to investigate the determinants that influence firms decision to choose among different voluntary standards within food supply chains. The key determinants explored is the role of transaction risks, i.e. internal and exogenous risks, in the adoption of different traceability standards. Their findings highlight that the transaction risks perceived by food firms play a significant role on the kind of traceability schemes to adopt. The authors also discovered that there exists a positive link between internal risks and the decision to implement complex traceability systems. Furthermore, it emerged from the authors' results that there also exists a negative relationship between the perceived exogenous risks and the complexity of the traceability standard chosen to be adopted by firms. Their conclusions were that exogenous transaction risk lead to the implementation of standards which do not imply strong co-ordination, and that perceived internal risks result in the development and implementation of complex traceability schemes that lead to closer supply chain relationships.

The PA theory examines the economic value of implementing traceability system in terms of the extent to which it reduces information asymmetry among actors in the chain and induces appropriate actions or compliance between principals (focal organisation) and agents (suppliers, producers or distributors) (Resende-Filho et al. 2008). This theoretical approach is widely utilised for understanding the relationships between traceability and food safety amongst the business operating in food supply chains (Resende-Filho et al. 2012). For example, using a case study of injection-site lesions in cattle, (Resende-Filho et al. 2008) developed a principal-agent game structure to identify optimal levels of traceability investment to overcome information asymmetry and to quantify incentive mechanisms necessary to induce the first-best behaviour on the part of risk-averse agents. The parameters used to solve this PA problem include: (a) the cost of injections at different locations;(b) the frequency of lesions, the reservation value for cattle; 9 the cost to the packer of discarding beef cuts with lesions, and the cost of traceability for each level of reliability (t). The key findings from the study were that by allowing the packer to create and use incentive mechanisms, a meat traceability system could induce feeders to adopt the quality-control practice preferred by the meatpacker. The principal-agent model, in the context of adverse selection , has also been utilised to examine how contracts that include traceability can be used to select against producers who cannot meet a processor's safety specifications conducted (Starbird et al. 2007). In this approach, the authors discovered that the motivation to select against unsafe producers depends on two key factors, including the magnitude of the failure costs and the proportion of the failure costs allocated to producers.

The process-oriented approach focuses on understanding the relationships between IT success variables and firm performance, and this is evaluated using structured information quality metrics (Bardaki et al. 2011). Information quality includes aspects of accuracy, relevance, timeliness, reliability, completeness, usefulness, credibility, trustworthiness, and being up-to-date, etc., (Lee et al. 2002). Within the literature, information quality metrics provide a quantitative method for evaluating the impact of IT: (a) within individual firms in terms of organisational performance (Madnick et al. 2009); cross-functionally between actors in terms of supply chain performance (Demeter et al. 2007), and terms of traceability, i.e. amount and quality of information aligned to material flow at different points in the chain (Anica-Popa 2012).

This exploratory research adopts the process-based approach underpinned by the structured metric-based approach for understanding the role and potential impact of IT for supporting traceability and to respond to critical challenges faced along the chain. This approach utilises information quality as a proxy measure to enhance understanding of the impact of IT on traceability both within individual firms and along red meat supply chains. The selection of the process-based approach also aligns with using the heuristics framework adapted from the work of Caridi et al (2010), and this aims to support the development of a quantitative measure for assessing the potential impact of low-cost mobile technologies on traceability along the red meat supply chain. The use of the structured process-based approach using information quality is described in more detail in the methodology chapter (Chapter 4).

2.10 SUPPLY CHAIN MAPPING TECHNIQUES

One of the most important activities involved with the assessment of traceability and visibility in a supply chain is supply chain mapping. Supply chain mapping is a technique used to visualise the flow of material and including the actors involved along different stages of the supply chain(Gardner et al. 2003). The benefit of conducting a supply chain mapping exercise is that it reveals inefficiencies and gaps in the links between of information and materials flow along the chain, thereby allowing for enhanced visibility to support improvement opportunities in the chain (Azevedo et al. 2011). A supply chain map is also essential because it provides a representation of the linkages and members of a supply chain(Wichmann et al. 2018), and supports the assessment of traceability and the role of IT at different points in the chain.

Within the literature, there exists a wide variety of supply chain mapping methodologies (Gardner et al. 2003). Prominent among them include the Supply Chains Operations Reference (SCOR) framework, Process Mapping diagrams, Value stream mapping (VSM), Integrated DEFinition method (IDEF0) and the system analysis system approach. The strength and weakness of each technique is described in the next section below.

2.10.1 SCOR FRAMEWORK

The SCOR framework is a reference framework commonly utilised in industrial and manufacturing supply chains to map, benchmark, and improve various levels of operations in the chain(Persson 2011). The SCOR framework consists of three levels of hierarchical mapping composition namely Level I, Level II, and level III: SCOR *Level I Process* provides a block of content for mapping the supply chain using five process types, namely: Plan, Source, Make, Deliver and Return. SCOR *Level II Process defines the* configuration level in which a supply chain process can be defined using core process categories. The process categories are defined by the relationships between a SCOR Process and a Process Type, e.g. “configured to order”(Huan et al. 2004). The SCOR Level III *Process activities* decompose processes in process elements, and describes inputs and outputs, process performance metrics and recommended best practices(Gulledge et al.).The benefit of the SCOR model is that it is widely utilised in many industrial supply chains for mapping and visualising internal and external operations of a supply chain(Persson et al. 2009). However, SCOR is limited to the operational level of the supply chain, while aspects of technologies and systems involved in the managing of the operations are not adequately covered.

2.10.2 PROCESS MAPPING

Process mapping is a general mapping method applied in most industry and businesses operations. They are used to develop a comprehensive view of internal and external processes within an enterprise. It is a mapping technique suitable at the level of business operations. Process mapping is used to determine how information is captured and manipulated to create value for customers (Banterle and Stranieri 2008). Process mapping can also be used to identify critical points along the value chain where information that is necessary to maintain full traceability is lost or in areas that require information quality improvement (Sterling et al. 2015). The main benefit with the usage of the flow chart is the flexibility in the variety of ways in which a process is described (Zhan 2016). However, the disadvantage of process mapping is the fact that it is limited to the main processes and does not provide a discrete mapping of internal sub-processes.

2.10.3 VALUE STREAM MAPPING

Value stream mapping (VSM) is another technique used in supply chain mapping.it is used to identify value-adding activities and those considered wasteful of materials and the flow of information and people(Dal Forno et al. 2014). A VSM is a visual representation of the flow of people, material, and information in a complex system (Gellad et al. 2016). The major disadvantage of VSM is its limited focus on lean supply chain management.

2.10.4 IDEF0

The Integrated DEFinition method (IDEF0) has also been suggested as a technique for mapping supply chains as well for investigating traceability (information and flow alignment) challenges both within organisation and external along the supply chain(Garrido Campos et al. 2009; Marconi et al. 2017). IDEF0 focuses on a high level of the activities of a process, showing the main activities and the input, output control, and mechanisms associated with each important activity(Aguilar-Saven 2004).

2.10.5 SYSTEMS THINKING APPROACH

Systems thinking offers a method for describing and analysing problems in such contexts, and is considered well suited to solving the complex and dynamic problems found in logistics and supply chain management(Holmberg 2000).In systems thinking approach, a supply chain is conceptualised as an extensive system comprising several subsystems (organisations) together with the relationships between them(van der Vorst 2000). Each subsystem can be described as encompassing inter-connected components separated from their environments by a system border(Wang & Zhang 2010).van der Vorst (2000) suggested a system view for mapping supply chain using four elements, namely: managed system, managing systems, information systems and organisational structure. The research adopted the system analysis approach for mapping the supply chain. In this approach, a supply chain is viewed as a large system characterised as organisations with eternal relationships linking one or more together in the chain. Figure 9 depicts the systems approach to the supply chain mapping across three layers: operations, technologies, and information. The operations layer depicts each orgaisational activity or series of activities used to produce, transform, or manipulate a product.This can be described in terms of the SCOR level 1 process. For example, a farm activity could include grazing, veterinary care, weaning. The technology layer depicts the technology infrastructure utilised to support business operations as part of organisational traceability practices. Technology components can include RFID systems, tablets, farm production software, tags, readers. The information layer depicts the information being capture based on the use of technologies and the activities at the operations. Information could include NVD documents and the associated data elements such as RFID tag number, breed of cattle/ shep, and age. By applying this framework, it is possible to generate a holistic understanding and mapping of organisational and inter-organisational traceability practices, including their interconnection between at the operation, technologies and information layers.

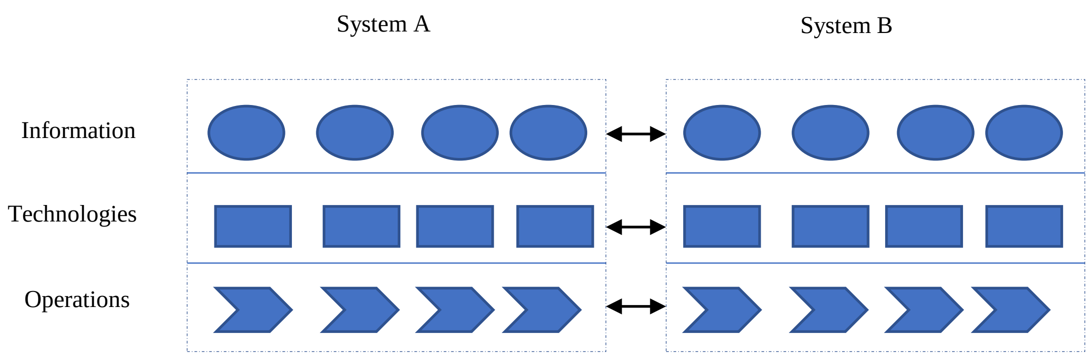


Figure 9: A Proposed systems-based approach for mapping organisational traceability practices in a supply chain

2.11 CHAPTER SUMMARY

This chapter has presented a review of the literature on the four key domains that will underpin this exploratory study. This review is intended to grant the reader sufficient knowledge with which to understand the remainder of the thesis and the work In the red meat supply chain, the literature reveals some of the critical challenges in traceability in areas such as provenance, meat safety, animal welfare and meat quality. In terms of traceability, the review revealed the increased importance and the opportunities for productivity, performance, and enhanced supply chain management using innovative IT and mobile system and sensors. The research has explored existing opportunities in framework and models for implementing traceability in the red meat industry and has developed a heuristic framework to guide the conduct of this research, based on the adaptation of the framework developed by Caridi et al. (2010). The framework will be presented in the next chapter. To achieve the objective of mapping a supply chain in this research work, a review of mapping techniques was conducted and a suitable strategy to enable a holistic analysis of organisational traceability practices is proposed. This mapping strategy allows for consideration of three layers of traceability, namely breaking down organisational traceability practices into three layers, operations, technologies, and information.

Chapter 3

Research methodology

3.1 INTRODUCTION

In the previous chapter, the research was introduced through a review of the various research domains underpinning this study. The outcome of the review led to the development of this research that aims to explore some of the critical traceability challenges facing small businesses in the red meat industry and to understand the role and potential impact of mobile technologies. This chapter describes the research methodology used to conduct this exploratory study. The chapter is divided into four major sections. **In section 3.2**, the research philosophy is discussed. This discussion involves the review of existing epistemological and ontological positions that could be used to explore the research problem of this study and describes the selected position taken. The research has taken an interpretivist and subjective philosophical position for this study. The justification for selecting this philosophical position is discussed later in this section. **In section 3.3**, the research strategy is discussed. This research utilises a three-phased approach to enable the conduct of this study which comprises of pre-intervention, technology intervention, and post-intervention. This remainder of this section also describes in detail the protocol for implementing the three-phased approach. In **section 3.4**, the research design is discussed, and this includes the approach to data collection, data analysis, data interpretation and presentation. The research uses a multiple case study design in the conduct of this study and applies a mixed methodological approach for data collection, analysis, and interpretation. **In section 3.5,** this chapter describes the approach used to interpret and discuss the findings from the study. It also describes measures taken to enhance the reliability of results generated from this study using the methodological approach presented. Finally, the ethics application protocol that was approved by the research ethics committee of the University of Tasmania and was utilised to facilitate the conduct of this study is outlined.

3.2 RESEARCH PHILOSOPHY

The research philosophy contains important assumptions concerning how a researcher views the world(Saunders et al. 2009). These assumptions provide guidance for conducting the research, such as the research strategy, and research design(Rubin et al. 2012). Two key aspects of research philosophy include ontology and epistemology (Rossman et al. 2003).

3.2.1 ONTOLOGY

Ontology relates to the philosophical study of the nature of reality (Cresswell 2013). Ontology addresses two critical philosophical questions: What is the form and nature of reality, and what can be known about that reality? (Ponterotto 2005). Ontological assumptions inform a researcher's epistemological assumptions which inform the methodology and method of data collection(Mack 2010).

Schuh et al. (2007) mentioned that two leading ontological positions include realism and relativism. According to the authors, ontological realism is a form of objectivism that assumes that the nature of reality exists independently of the thinking beings and knowing involves the correspondence between the world and the mind. Ontological relativism is a form of subjectivism, which is of the view that the existence and type of objects of any kind are subject to the thinking beings. This view holds that there is no absolute truth to the world; instead, the reality is based on individual constructions that are highly dependent on the individual building the constructions. A third ontological position is critical realism. According to (Morrow 2007), this holds that reality exists but cannot be fully comprehended by the researcher.

The research focuses on exploring traceability challenges and risks impacting small businesses along the supply chain. The purpose is to understand the role and potential impact of the implementation of low-cost mobile technologies in responding to some of the critical traceability challenges facing red meat small businesses in their supply chains. Given the context of this study, the researcher is inclined to take a subjectivist ontological position where the reality of traceability and risks and challenges are constituted from the view of the participants working in the supply chain. This approach is considered a more practical approach to understanding logistical and traceability related challenges in a supply chain contexts(Solem 2003).

3.2.2 EPISTEMOLOGY

Epistemology is concerned with ways of knowing and learning about the social world (Scotland 2012). Epistemology focuses on questions such as: how can we know about reality, and what is the basis of our knowledge? (Ritchie et al. 2013).

Two main epistemological paradigms exist, namely: interpretivist/constructivist; positivist/objectivist (Tuli 2011). The interpretivist/constructivist paradigm is based on a relativist ontology in which there can be as many realities as there are participants, including the investigators' (Morrow 2007). This paradigm implies that meanings are often co-constructed by participants and researchers, thus implying a transactional and subjectivist epistemology. The positivist/objectivist paradigm is based on a realist ontology. This paradigm holds that reality is driven by natural laws, and there are governed by laws of cause and effect and are therefore measurable, predictable and controllable (Dieronitou 2014).

Since the researcher explores traceability challenges facing small businesses in the Tasmanian red meat industry from the perspectives of the participants involved by taking a subjectivist ontological position. This balanced approach is essential because this research aims to contextualise the key findings that emerge from this study on the traceability challenges faced by small businesses, and the role and potential impact of IT on the supply chain from the different perspectives of small business owners in the red meat supply chain.

3.3 RESEARCH STRATEGY

The research strategy is the plan and procedure for answering the research questions (Wedawatta et al. 2011). According to Yin (2006), the adoption of a suitable research strategy involves the analysis of three factors, namely: *the type of research question; the extent of control over behavioural events; and the general circumstances of the phenomenon to be studied*. These three factors were taken into consideration in the development of an appropriate research strategy for this study. This research uses a case study strategy to guide the conduct of this exploratory research.

The research aims to answer the following research questions:

1) How can low-cost mobile technologies be utilised and deployed amongst small businesses in red meat supply chains to support traceability and for responding to challenges faced?
2) What criteria do small businesses in red meat supply chains use in evaluating the role and potential impact of low-cost mobile technologies in supporting traceability and for responding to challenges faced?

3) How can a small business traceability framework be developed to support the implementation and evaluation of low-cost mobile technologies to support traceability and for responding to challenges faced?

The justification for the use of a case study strategy is as follows**. Firstly,** according to Yin (2006), the case study strategy is pertinent when your research addresses the nature of the research question, that is whether it is a descriptive question (what happened?) or an explanatory question (how or why did something happen?). As shown in the research questions stated above, this study is focused on answering the “how” and “what” questions, and as a result, a case study strategy is considered the most suitable. **The first research question** focuses on the explanatory aspect of the research, in which the researcher is interested in *exploring and understanding how low-cost information technologies can be most effectively and practically deployed amongst small businesses operating in red meat supply chains to support traceability and for responding to challenges faced in the chain*. The second research question focuses on the “what” question, in which the researcher is interested in understanding and explaining *how small businesses perceive the role and potential impact of utilising low-cost IT in their supply chains for supporting traceability at different points and for responding to challenges faced in the chain.* The third research question focuses on the “how” question, in which the research will seek to develop new traceability framework, based on field evidence gathered in the study, to enhance understanding and support the implementation and *evaluation of low-cost IT amongst small businesses to support traceability and for responding to challenges faced at different points in the chain.*

Secondly, the case strategy is utilised when the researcher has little or no *control over behavioural events*. As this study is qualitative and subjectivist in ontology, the researcher has no control over behavioural events of the participants and businesses involved and instead focuses on the perspective of small businesses in terms of their experiences, challenges, and potential opportunities for supporting traceability using low-cost mobile technologies. The research will explore traceability challenges facing small business from their perspectives and aims to understand the perceived role and the potential impact that low-cost mobile technologies can have on traceability both within individual firms and also along the supply chain. In conducting this study, the researcher relies on the experiences and challenges of small business owners in providing their feedback concerning how and to what extent did the deployment of new technologies impact their capacity to assess and respond to critical challenges faced in their supply chains.

Thirdly, a case study strategy is considered appropriate when the researcher is focused on understanding the *general circumstances of the phenomenon to be studied. In this study,* these general circumstances are potential traceability challenges facing most Tasmanian small businesses, and what role and impact can have in responding to some of these challenges at different points. As discussed in Chapter 1 and Chapter 2, small businesses are exposed to multiple traceability challenges that impact their ability to respond to changing consumer demands and preferences and enhanced food safety regulation. These challenges relate to issues of provenance, meat safety, meat quality/authenticity, and animal welfare. Most traceability frameworks and models developed for responding to many of these challenges faced in red meat supply chains have focused on large businesses within integrated chains. However, for most small businesses very limited number of frameworks existing for supporting and enhancing traceability in fragmented chains have been developed. Using a case study strategy, this research aims to understand traceability challenges facing small businesses operating in different parts of the red meat supply chain and to understand what new roles and the potential impact can low-cost technologies have in improving traceability at different points and for responding to some of the critical challenges faced. Based on evidence generated from this study, the research will also develop a framework to support a better understanding of how IT can be deployed most timely and effectively amongst small business along red meat supply chains.

The primary strategy utilised in this study is a multiple case study using a three-phased approach. This three-phased strategy allows the researcher to explore traceability challenges amongst small businesses operating within the Tasmanian red meat supply chain and to understand the role and potential impact that specific low-cost mobile technologies can have in responding to these challenges along the different segments of the red meat chain. In the next section, the case study strategy utilised in this research is discussed.

3.3.1 CASE STUDY

A case study is an empirical study that investigates a phenomenon in a real-life context, especially when the boundaries between phenomenon and context are not evident (Myers et al. 2002). Case studies have been used in many different areas of information systems (IS) research and are known to provide versatility in design. This is because case studies usually combine data collection methods from multiple sources such as archives, interviews, questionnaires, and observations, and this may also include other evidence (e.g., words), quantitative (e.g. numbers) or both (Eisenhardt, 1989). The clear benefit is its versatility in those findings generated. The findings from case studies can be used to provide a description, test theory, or to generate new theory from cases in the case of interpretive research. In selecting a case study strategy the research took into consideration some essential factors, and these include the ability to: a) focus on one or several cases that are explored in depth; b) integrate diverse styles of (observational) evidence; and (c) sheds new light on a broader population, which it represents in an imperfect manner(Gerring, 2016). It was also important that the suggestion of Cavaye (1996) be taken into consideration in selecting a suitable case study design, and that includes when the research:

- Does not explicitly control or manipulate variables;
- Studies a phenomenon in the natural context;
- Studies the phenomenon at one of a few sites; and
- Makes use of both qualitative and quantitative tools and techniques for data collection and analysis.

The first consideration requires that the research focuses on an in-depth understanding of the context of a phenomenon without interfering variables that might emerge from the cases or from a different aspect of a phenomenon. In this study, the research focuses on to understand and exploring traceability challenges amongst small businesses, and the role and impact of information technology. The key phenomenon being explored relate to : (1) traceability challenges amongst small business operating; and (2) the role and potential impact in their supply chains. Based on evidence gathered from the field, the research will develop a new traceability framework for evaluating the role and potential impact of low-cost technologies on traceability at different parts of the red meat supply chain. The second consideration relates to exploring a phenomenon in the natural context. In this study, the research explores traceability in a small business context operating within the Tasmanian red meat industry. This includes exploring small business owner's experiences and challenges, including potential opportunities for traceability at different points along the red meat supply chain using low-cost technologies.

The third consideration relates to studying phenomenon at one of a few sites. In this study, multiple small businesses operating along different parts of a lamb and beef supply chain in Tasmania have been selected and explored. This approach allows the researcher to explore the same phenomenon in different business contexts and to use the differences to refine and generate new concepts from the study.

The fourth consideration relates to the ability to combine both qualitative and quantitative tools and techniques for data collection and analysis. In this study, a case study strategy has been selected because of the versatility in data collection procedures that it offers. In conducting this research, the research has utilised both qualitative (interviews) and quantitative (survey, technical data) techniques to answer the research questions and to support the generation and refining of a new traceability framework. This data collection procedure utilised for this study is discussed in Section 3.4.

3.3.1.1 SINGLE VS MULTIPLE CASE STUDY

Several authors have distinguished between the use of single and multiple case strategy in IS research(Baxter et al. 2008; Benbasat et al. 1987). A single case is often used where it represents a critical case or an extreme or unique case", whereas multiple cases use more than one to compare whether the findings of the first case occur in other cases. As compared to the single case strategy, multiple-case strategy improves the robustness and rigour of case study research because it focuses more on exploring theories through replication rather than through sampling logic(Zainal 2007). This research will utilise a multiple case study strategy because it provides more versatility and rigour in research findings as compared to a single case study (Myers et al. 2002). Miles(1994) mentioned that a multiple case study approach helps to ensure methodological rigour of the study rigour strengthens the precision, validity and stability of the findings. Yin (2006) also stated that evidence from multiple cases is often considered more compelling in research. Zainal (2007) underscores the importance of multiple cases study to help in raising the confidence and ensuring the robustness of method and evidence through pattern matching, and this involves linking several pieces of information from the same case to some theoretical proposition, and as such can enhance and support previous results. The research finds that a multiple case study approach will enhance the reliability of findings generated through this study as compared to the use of single case study.

3.3.1.2 STRATEGY FOR CASE SELECTION

The criteria utilised follows a pragmatic approach that includes accessibility to firms, geographical proximity, availability and willingness to participate in the interventions. The research also ensured that the selected participants: (a) agreed to remain available throughout the study and were willing to participate in any form of intervention; (b) and possessed the ability to communicate experiences and opinions in an articulate, expressive, and reflective manner(Spradley 2016). The research also ensured that selected participants are knowledgeable about or experienced with a phenomenon of interest(Creswell et al. 2017).

Four case studies are explored in this research, and their characteristics include typical case, unique case and opportunity cases. The justification of these choices selection of strategies is discussed. Firstly, because this study is exploratory and takes a multiple case study research design, the typical or ordinary case is found suitable to "describe and illustrate what is typical," (Patton, 1990, pp. 173).In this context, the research explored a typical case study of a supply chain involving small businesses and their traceability approach. Case study 1 and 2 are typical case studies of a fragmented Tasmanian red meat supply chain with small businesses.

Secondly, the research is interested in identifying and selecting a case study 3 with maximum variation. This was considered an interesting case and involved a Tasmanian lamb supply chain with all participants involved in the study from farm to retail butcher. The case was considered an interesting the actors were visible to one another, suggesting the possibility of exploring full traceability across different stages of this chain. While the selection of cases that are outliers from normal and typical cases could pose problems in integrating findings, this feature has the potential to increase the strength of the results (Patton, 1990). Patton also recommends that "any common patterns that emerge from great variation are of particular interest and value in capturing the core experiences and central, shared aspects, " of a case. The aim of selecting this case was to explore the experiences and traceability of small businesses indifferent different supply contexts in order to generate new insight into the role and potential impact of IT along the supply chain.

Thirdly, the research also explored opportunity cases where the researcher faced difficulties in not recruiting all the key participants in the red meat supply chain beyond the local butcher. This is case study 4. This was also a case in which some firms initially agreed to be involved in the study but later decided not to continue because of availability, or other business reason. However, the focal company was interested in pursuing opportunities for traceability improvement in the study. The next section summarises the three-phased approach that will be utilised to guide the conduct of this exploratory research

3.3.2 THREE-PHASED APPROACH

In implementing the case study strategy, a three-phased approach is utilised. These phases includes : (a) Phase 1- pre-intervention; (b) Phase 2- technology intervention; and (c) Phase 3 -post-intervention evaluation. The pre-intervention phase includes three steps : (a) industry familiarisation; (b) supply chain mapping, (c) and baseline data collection. The technology intervention includes the proposal, development and implementation of some low-cost mobile technologies within individual firms and along the red meat supply chain to enhance traceability and for responding to some of the critical challenges faced by small business owners along the red meat supply chain. The post-intervention evaluation involves the collection of feedback from the focal participants within the businesses that participated in Phase 1 and Phase 2, to understand how and to what extent did the intervention impact visibility and capacity for traceability in responding to the challenges faced. The detailed application of this three-phased approach is presented in the next section below.

3.4 RESEARCH DESIGN

Research design can also be defined as the framework or basic structure within which a given investigation takes place (Bryman et al. 2001). This multiple case study design utilised in this study is organised using the three-phased approach, namely pre-intervention, intervention, and post-intervention. The discussion of each phase is presented below.

3.4.1 PHASE 1: PRE-INTERVENTION

The pre-intervention phase consists of preliminary steps taken by the researcher to explore and become familiar with the critical traceability challenges facing Tasmanian small businesses in the red meat industry. These involve three steps, namely: (a) industry familiarisation; (b) supply chain mapping and technology audits; (c) and quantitative baseline data collection to evaluate focal participant level of visibility to the potential traceability challenges faced in the supply chain.

3.4.1.1 STEP 1: INDUSTRY FAMILIARISATION

The purpose of industry familiarisation step was to obtain first-hand information from subject matter experts working within the Tasmanian red meat industry on the critical issues, traceability challenges, and risks that could potentially impact Tasmanian businesses (mostly small businesses) in their supply chains. The familiarisation phase is conducted in the following sub-step:

3.4.1.2 SUB-STEP 1: IDENTIFICATION OF INDUSTRY STAKEHOLDERS

The research conducted a preliminary search of the key agencies within the Tasmanian red meat industry that is aligned to traceability practices both within individual firms, and along the supply chain at different segments. The focus of this search was limited to beef and sheep meat products. These meat products were the focal points of the investigation given their increasing economic significance to the red meat industry.

Based on this internet search, three agencies were found to be closely aligned with traceability in the Tasmanian red meat supply chain. The criteria for their selection was based on individual assessment of the departmental goals for each agency and how that relates to traceability in the red meat supply chain. The first department is the Department of Primary Industries, Parks, Water and Environment (DPIPWE). The second agency is the Australian Meat Industry Council (AMIC). The third agency is the public health liaison of the Hobart city council. At DPIPWE, 5 different departments were identified as having a direct relationship with traceability and were able to provide more information regarding potential challenges facing small businesses in their supply chains and these included (a) Biosecurity and Traceability; (b) Animal Brands; (c) Meat Safety/Integrity; (d) Animal Welfare, and;

(e) Agricultural Veterinary (Agvet) and Chemicals. DPIPWE also provides regulatory oversight at both state and local government level for all businesses operating within the Tasmanian red meat industry in terms of traceability at different parts of the chain.

The Biosecurity and Traceability department is focused on ensuring compliance with traceability as well as minimising the risk of severe disease and poor animal welfare. The office of Animal brands provides oversights over businesses utilising earmarks, body brands and tags for sheep and cattle by compiling and maintaining and register for the state. The food safety and integrity office ensure that Tasmanian food producers and processors comply with state food safety policies and legislation aimed at protecting Tasmania's reputation as a producer of safe and clean food. The office also provides certification to meat processors tested in gaining access to overseas consumer markets and other premium markets around the world under the Tasmanian brand. Office of animal veterinary focuses on animal welfare by ensuring that owners or other actors responsible for animals comply with legislation involving the proper handling of livestock along the supply chain. The Agvet Chemicals office play an important role in traceability by ensuring that meat products are free from chemical residues which may pose potential health risks to humans and the environment.

A second non-governmental agency, the Australian Meat Industry Council (AMIC), was also contacted. AMIC is the peak council representing the post-farm-gate meat industry and conduct pro-active engagement with government and non-government agencies to improve the recognition and performance of the meat processing and retail industry at the policy level by reducing bureaucratic red tape[37]. Currently, AMIC focuses on enhancing the capabilities of independent local butchers to adapt to changing business conditions in the red meat industry in terms of new regulatory policies, demand for traceability, and changing market requirements in meat processing and retail in the Australian red meat sector. AMIC also works closely with the government to provide reforms on a range of socio-technical issues impacting small retail supply chains in Australia. The research contacted a local

[37] https://amic.org.au/wp-content/uploads/2019/06/AMIC-Annual-report-2017-2018-endorsed-by-the-board-21.06.19.pdf

AMIC representative in Tasmanian to provide input of traceability challenges facing small retail butcher shops in the region.

A third agency contacted is the Liaison office in charge of public health and food safety at the Hobart city council. This council office performs the role of a Food Safety Regulatory Agency at the local level by conducting routine inspection and investigations into concerns relating to: (a) foreign matter found in food; (b) poor personal hygiene; (c) pest infestations; (d) unclean food premises; (e) food premise waste storage/refuse; (e)poor food storage/handling practices[38]. The Hobart city council also performs the role of Food Safety Regulation Agency overseeing food retail businesses operating in the Hobart area. One participant was invited and agreed to participate in this study. The stakeholders selected from within these agencies i.e. DPIPWE and Hobart city council, performed important roles aligned to those performed at the Local Government Level and Food safety Regulatory Agencies.

3.4.1.3 SUB-STEP 2: INVITATION TO SUBJECT MATTER EXPERTS

Following the identification of those departments that were aligned to traceability practices in the Tasmanian red meat supply chain, the research then proceeded to contact each department using email and telephone published on their website. The email address was found to be general email assigned to the information desk. A separate email was sent to each department using the information desk email, with attention placed on the header to highlight department in focus. The research sent a short description of the study as part of the introduction email and attached relevant documents approved by the research ethics committee for recruitment of participants for the study (See Appendix A). The email also asked each participant to indicate in their responses if they were interested in participating in the study. In addition to this protocol, the research also contacted some prospective participants via telephone to discuss further on the research study and to obtain their consent. Based on this protocol, all six agency heads agreed to participate in the study. A total of 7 industry stakeholders, including subject matters experts, were invited and agreed to participate in the study. These include 5 participants from DPIPWE, overseeing traceability issues along the red meat supply chain at the local and state level in Tasmania; 1 participant from Hobart city council representing a Local Food Safety

[38] https://www.hobartcity.com.au/Community/Public-health/Food-safety

Regulation Agency (FSRA); and 1 participant from AMIC. Table 2 below shows the participant profile for all subject matter experts that were involved in the study. It shows the participant ID that is allocated to each subject matter expert to provide anonymity to their responses. It is essential to mention that for AMIC, a local representative was selected to be involved in the study, particularly focused on AMIC Tasmania region. Finally, the research received a signed copy of the consent sheet, and specific dates for individual interviews were arranged for each participant based on their availability.

Table 2: Participant profile in the industry familiarisation phase

	Industry agencies				
Traceability program	DPIPWE	FSRA	AMIC	Position	ID
Biosecurity and Traceability	✓			Program Head	P01
Primary produce & Meat safety	✓			Program Head	P02
Agricultural and Veterinary chemicals (AgVet Chem)	✓			Program Head	P03
Animal brands	✓			Program Head	P04
Animal welfare	✓			Program Head	P05
Hobart city council (Retail-Food Safety Regulation Agency (FSRA))			✓	Program Head.	P06
AMIC Tasmania		✓		State Rep	P07

3.4.1.4 STEP 2: SUPPLY CHAIN MAPPING

The supply chain mapping step included all activities required to produce a map of the Tasmanian red meat supply chains involving small businesses operating at different segments. A total of five sub-steps were utilised in producing a supply chain map as follows.

3.4.1.4.1 SUB-STEP 1: SURVEY OF PROSPECTIVE CASE STUDY PARTICIPANTS

In sub-step 1, the researcher conducted a preliminary survey of Tasmanian small businesses operating within the red meat industry from farm production to retail. The internet search made use of online internet search directories such as Google search, Yelp, and yellow pages directory. The purpose of this search was to identify and draw out a list of prospective supply chain partners that could be invited to participate in this study across the three phases that include: (a) pre-intervention - supply chain mapping and baseline data collection; (b) technology intervention; and

(c) post-intervention evaluation. The search was limited to the following regions, namely: Hobart and Greater Hobart (Glenorchy), Derwent Valley, and Launceston area/Northern Midlands. Given the limited budget allocated to the study, it was necessary to constrain the research using the geographical proximity criteria to minimise the cost of transportation. In total, 30 small businesses operating within the geographical area selected for this study and in different parts of the red meat supply chain in Tasmania were identified. These small businesses included *farmers, cattle transport, saleyard, meat processors, secondary meat processors, wholesalers, cold chain operators, and retail butchers*.

From this initial list of 30 small businesses, 4 local retail butchers were then selected to serve as the focal company through which their red meat supply chains will be mapped. The retail butchers were selected because of role and significance in the domestic market of the Tasmanian red meat industry, given their widely acknowledged status as being the second-largest small businesses meat retailer for fresh meat products[39]. These include 3 retail butchers located in Hobart region and 1 butcher located in Launceston.

3.4.1.4.2 SUB-STEP 2: INVITATION AND SELECTION OF CASE STUDY PARTICIPANTS

In sub-step 2, the researcher contacted the 4 local butchers by visiting their respective offices to discuss the purpose of the research project and to seek their consent as participants in the study. Each butcher was provided with a copy of the recruitment materials as approved by the research ethics committee of the University of Tasmania. The recruited materials included an information sheet, an advertisement sheet, and a consent form. Then additional 6 extra copies of recruitment materials were given to each butcher to invite other actors in their supply chains who will then contact the primary investigator directly through the mobile phone number affixed to the recruitment materials or via email to indicate interest in participating in the study. The six copies of invitation materials were provided to cover the major operations of the red meat supply chain for each butcher, and they include *farmers, cattle*

[39] https://www.mla.com.au/globalassets/mla-corporate/prices--markets/documents/os-markets/red-meat-market-snapshots/2018-mla-ms_global-beef.pdf

transport, saleyard, meat processors, secondary meat processors, wholesalers, cold chain operators, and retail butchers.

In total, 23 small businesses aligned to 4 retail butcher supply chains were invited to the study. The invitation was addressed to owner-managers and operations manager alone. They were considered the key informants for this study and were preferred because of the knowledge they possess of their supply chains, and their ability to provide details on the traceability and level of visibility of supply chain in relation to red meat. In some businesses, more than one participant was invited, and this was dependent on the organisational structure of the firm. Of the 23 participants invited, only 11 participants, including 3 retail butchers eventually agreed to participate invited for this study across all phases where necessary. One retail butcher and a local farmer dropped out of the study during the invitation and selection process. The keys findings from the recruitment and selection of participants are presented in detail in Chapter 4 (See section 4.3).

Table 3 below shows the case study participants that are involved in this study. Some participants were involved in one phase were other participant engaged with the researcher in all the three phases. The details of participant engagement in the three phases are presented in Section 3.5 (research data collection section). In Table 3 shown below, each participant held top positions in their respective firms that comprise of owner-managers, joint owner-managers, and operations managers. The participants were also assigned an identification tag for anonymity. Also, some businesses/participants performed multiple operations within their individual businesses and also along the chain. For example, the cattle farmer/transport and the lamb farmer performed the operations of a breeding property and feedlot where they grow, wean new calves, and feed them until the animals are ready for sales. The saleyard performed the role of the small business auction by providing a platform for livestock sellers to sell their animals to prospective buyers through auction sales. The stock agent plays the role of a livestock buyer by contacting prospective sellers such as farmers and saleyard to purchase new stocks. The wholesale played dual roles of a wholesale meat seller and a third-party carcase/cold chain delivery operator to retail the butchers ordering through their businesses. Retail butcher 2 played two roles, and these includes the roles of a cold chain logistics provider to the butcher store and a meat retailer selling different cuts of meat to customers. Retail butcher 1 and 3 only performed single roles as meat retailer for their respective businesses. In total, 11 participants from 9 businesses operating in different parts of a beef and lamb supply chain were invited and agreed to participate in this study.

Table 3: Profile of supply chain participants that participated in the research study

Supply chain operation	*Operational roles*	*Position*	*No of participant*	*Participant ID*
Cattle Farmer/Transport	Breeding property	Owner manager	1	P08
Lamb Farmer/Transport	Breeding property	Owner manager	1	P09
Saleyard	Small business auction plus	Saleyard operations A	1	P10
		Saleyard operations B	1	P11
Stock agent	Livestock buyer	Owner manager	1	P12
Meat processor	Meat processing	Owner manager	1	P13
Wholesale	Wholesale retail/Third Party cold chain Logistics provider	Owner manager	1	P14
Retail butcher 1	Meat retailer	Owner manager	1	P15
Cold chain/Retail butcher 2	Cold chain logistics provider	Owner manager A	1	P16
	Meat retailer	Owner manager B	1	P17
Retail butcher 3	Meat retailer	Owner manager	1	P18
Total businesses=9		**Total number of case study participants=11**		

The participants covered the key supply chain operations in the red meat industry, namely; *farm production, cattle transportation, stock agent, sale yard operation, meat processing, cold chain transportation, wholesales/storage, and retail*. Some participants held dual positions and were treated as a single firm and single participants. The organisation of the case study across multiple red meat supply chains are as follows:

- Case study 1 (pre-slaughter beef supply chain segment): The supply chain comprises of 2 small businesses, and they include: ((a) farmer/cattle transport (1 participant); and (b) saleyard operations (2 participants);

- Case study 2 (post-slaughter beef supply chain segment): The supply chain comprises of 3 small businesses, and they include: (a) stock agent (1 participant); (b) wholesale(1 participant); and (c) retail butcher (1 participant)
- Case study 3 (lamb meat supply chain): The supply chain comprises of 3 small businesses, and they include: (a) Lamb farmer/transport (1 participant); (b) meat processor (1 participant); and (c) cold chain/retail butcher (2 participants).
- Case 4 (retail butcher): This case study involved only a retail butcher (1 participant) aligned to a beef supply chain in Tasmania.

3.4.1.4.3 SUB-STEP 3: STRATEGY FOR SUPPLY CHAIN MAPPING

The strategy for the supply chain involves preliminary discussion with the 3 retail butchers participants to arrange a time to discuss their knowledge of the supply chain in both the forward (i.e. farm to retail) and back direction (retail back to farm) and to identify the segments where fragmentation occur in their understanding of the chain. Based on the discussion held with the case study participants, two supply chain mapping strategies are utilised, namely: Strategy A(linear/whole of chain) and Strategy B(fragmented strategy). In strategy A, a linear supply chain mapping strategy is utilised if all the butcher: (a) have a linear relationship with other actors aligned to the supply chain; (b) along with the key actors in the chain are able to provide a full description of traceability of the red meat product that links to one another in information and material flow alignment, and product transformation along the chain; from retail back to the farm and vice versa; and (c) including the key actors agree to participate in the study. In a linear supply chain mapping strategy, a single product (beef or lamb) is followed from the retail back to the farmer, or vice versa and all activities involved in converting the live animal to final meat steak are mapped and modelled across three levels: operations, technologies, and information.

In strategy B, a fragmented supply chain mapping strategy is utilised if: (a) no direct relationship exists with the butcher and case study participants; (b) the butcher and actors are unable to match a description of traceability of the red meat product including how information and material flows align at different segments of the chain including during transformation, and (c) one or more actor in the chain are unwilling to participate in the mapping exercise to guide a detailed description of all the key actors in their supply chains. A fragmented chain mapping strategy breaks the supply chain of the butcher into two or more major operational segments depending on the information-sharing approach, level of visibility of partners, and approach to traceability. The fragmented mapping approach will utilise the following segments and they are: (a) Pre-slaughter: farm ➔cattle transport➔saleyard/stock agent➔; and (b) Post-slaughter: processor➔ cold chain transport➔Wholesale➔retail. Each segment can also represent the minimum requirement of traceability amongst small businesses in what can be described as a one-up one-down approach. In some cases, within a fragmented chain scenario, the link between pre-slaughter and the post-slaughter segment may be the saleyard since most livestock transactions occur through them in Tasmania. Most Tasmanian businesses operating in the red meat industry purchase cattle/sheep in two ways, namely either through live auctions using the saleyard/stock agents as the sales point or by purchasing directly from the farmer in what can be described as over the hook transactions. To recruit participants for the pre-slaughter segment, the researcher utilises the same protocol for step1 and step 2 to contact interested farmers aligned to the same saleyard in which the butcher usually buy their beef or sheep from.

3.4.1.4.4 SUB-STEP 4: MAPPING ORGANISATIONAL TRACEABILITY PRACTICES

The mapping exercise focuses on capturing the key components of organisational operations, technologies and information that are aligned to traceability practices in the red meat supply chain. This is achieved using the adapted supply chain mapping framework proposed in this study based on the literature review (Chapter 3, see section 2.9.5). Depending on the mapping strategy utilised (i.e. fragmented or linear), the organisational traceability practices for each individual firm is mapped across three-level, namely operations, technologies, and information. Figure 10 below shows an example of the application of the mapping framework in a fragmented setting. As shown below, at the operations level the researcher maps the series of observable activities in which the businesses engage in as part of its organisational processes being used to transform, manipulate or produce a meat product. At the technologies level, an audit of the range of technologies which is utilised to support the different range of organisational activities that are engaged in by the firm is also mapped. At the level of information, the types, the types, format and quality of information generated by each activity or received as part of the movement of materials (i.e. beef/sheep) internal or externally along the supply chain are captured and modelled.

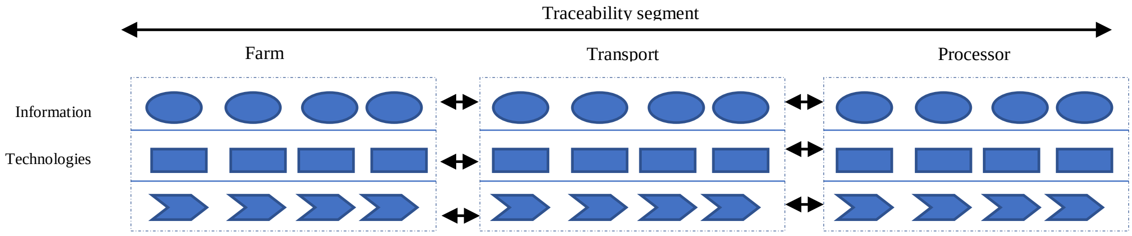


Figure 10: An example mapping of a focal company in a supply chain segment (i.e. farmer, cattle transport, and processor

3.4.1.4.5 SUB-STEP 5: FEEDBACK MEETING WITH CASE STUDY PARTICIPANTS AFTER SUPPLY CHAIN MAPPING STEP

After the supply chain mapping step, the participant held a feedback meeting with the case study participants to traceability challenges faces, findings from the supply chain mapping exercise, and to solicit their involvement in baseline data collection to ascertain areas of information and visibility where technology intervention is able to impact positively along the supply chain.based on this feedback the focal participant is selected to progress to step 3(baseline data collection phase). Based on the feedback received from the meeting, two key outcomes are obtained, and these are (a) identification of focal firms and participants for baseline data collection, technology intervention, determination of duration of intervention; and (b) identification of most practical location for technology intervention to enhance the visibility and capacity for traceability in the supply chain segment. The number of businesses and respective participants that agreed to engage with the research to obtain baseline data is presented in section 3.5 (research data collection).

3.4.1.5 STEP 3: QUANTITATIVE BASELINE DATA COLLECTION

Baseline data collection involves the selection of a focal company and the application of the proposed heuristics framework to support the quantitative visibility assessment of each focal company in relation to the potential traceability challenges it faces in its supply chain segment. Table 4 below shows the visibility assessment for traceability information focused on meat provenance, meat safety, meat quality, and animal welfare. These traceability challenges, proposed based on the review of literature, include meat provenance, meat safety, animal welfare, and meat quality. Each participant was consulted to provide suggestions on some of the traceability challenges it faces and their relationships to visibility. The heuristics framework measures visibility as the total sum of the amount and quality of information that a firm has concerning this traceability information using three IQ criteria, namely *freshness, accuracy and completeness*.

In a linear supply chain mapping setting in which all traceability challenges (i.e. provenance, meat safety, meat quality, and animal welfare) were perceived by supply chains to be relevant to their businesses, then a total visibility assessment is conducted. This is also based on the extent of supply chain links between the focal firm and other actors involved in the segment. In a fragmented supply chain, node visibility assessment is utilised by evaluating information quality criteria within a specific segment and involving one or more traceability challenges depending on the agreement with the actors involved. Each focal participant selected in the supply chain is asked to prioritise traceability challenges being faced based on their level of visibility, and this resulting traceability priority is assessed using the visibility framework adapted from Caridi et al. (2010).

In applying the framework, visibility is measured as the amount and quality of information that a focal firm has in relation to this traceability information (i.e. meat provenance, meat safety, meat quality, and animal welfare) using three IQ criteria, namely freshness/currency, accuracy and completeness. In this research context, freshness is defined as the degree of information "synchronisation" with business partners. Accuracy is defined as the degree of conformity of the shared information with its actual value. Accessibility is the degree of completeness of shared information. Based on these quality metrics, it is possible to evaluate supply chain visibility as being the sum of visibility of information that any specific company has access to and views at different nodes/segments in a supply chain.

Table 4: Visibility assessments of traceability information(adapted from Caridi et al. (2010)

Retail Butcher	Safety (s)	Quality (q)	Provenance (p)	Animal Welfare
Completeness	$t_{c,s}$	$t_{c,q}$	$t_{c,p}$	$t_{c,w}$
Accuracy	$t_{a,s}$	$t_{a,s}$	$t_{a,p}$	$t_{c,q}$
Freshness	$t_{t,s}$	$t_{f,q}$	$t_{f,p}$	$t_{c,q}$

The four types of traceability information flows have been identified based on a review of literature of potential traceability challenges impacting the red meat supply chains, and they are *s=safety, q=quality, p=provenance and w=animal welfare.* Therefore in evaluating *traceability information flows =“t”* the approach is to use the formula t=(s,q,p,w). For each type of traceability information flow “t”, the following definitions are used:

1. Meat Safety: Information related to the chemical, microbiological or physical attributes of food products;
2. Meat quality: Information describing the compositional quality (lean to fat ratio, meat percentage, intramuscular fat, marbling, protein, and muscle area); functional quality (e.g. pH, and cooking loss); and eating quality or palatability of meat (e.g. appearance, juiciness, tenderness, and flavour)(ElMasry et al. 2010);
3. Animal welfare: Information that describes the welfare status of an animal along the supply chain. Information includes the treatment animals receive, e.g. animal care, animal husbandry, and humane treatment during transport and slaughter; and
4. Provenance: Information describing the origin, history and location of a product along the supply chain, e.g. geography, region, or country of origin.

Using the three information quality metrics provided for defining visibility (freshness; accuracy; amount/quantity), Table 4 above also illustrates how assessment calculations for each type of traceability information are being generated and how a visibility index is being calculated at each supply node for c=completeness (quantity); a=accuracy; and, f=freshness. Where completeness is described as the quantity of information, and freshness and accuracy are defined in terms of the quality of information. In implementing this framework in the case studies, participants are requested to use a four-point rating scale to conduct a self-assessment of the visibility score for each type of traceability information (1-low to 4-high). This quantitative data is analysed and presented in Chapter 4.

3.4.2 PHASE 2: TECHNOLOGY INTERVENTION

The technology intervention phase involves some steps that were performed to select, develop, test and successfully deploy specific low-cost mobile technologies at the location of the focal company. These steps include identification and selection of perceived traceability challenges based on supply chain mapping and baseline data collection; technology proposal and design of mobile applications, pilot technology testing, training of participant, and final deployment.

3.4.2.1 STEP 1: FEEDBACK MEETING WITH FOCAL COMPANY

The first step involves preliminary meetings were held with small business owners that agreed to discuss low-cost mobile technologies alternatives that can be deployed to improve areas of visibility and traceability internally within their firms externally along with their supply chains. Another key focus of the meeting is to identify and prioritise technology intervention points that are most practical and less disruptive to business operations.

3.4.2.2 STEP 2: TECHNOLOGY PROPOSAL AND DESIGN

The second step involves the proposal, design/selection, development, pilot testing and implementation of the technologies proposed. The findings from Phase 1, and Phase 2 (step 1) directly supported the identification of traceability technology foci for each case study. In the technology proposal stage, the researcher proposes specific low-cost technology that could be developed and deployed timely and most effectively with minimal obstruction to individual firm's operations. The design phase involves mutual contributions from the participants on the nature of technology, design structure and pattern, and customisation. The criteria for the selection of technologies was unique to each participant's needs. Each participant could contribute to the final selection of the technology by providing suggestion and feedback regarding if and how the proposed technologies could fit into their existing business practices and supply chain operations. This consideration was crucial because, without participants feedback, it will be impossible to implement the technologies.

For the mobile technologies developed, each participant was then asked to select the preferred UI as well as make changes in a way that reflect their business needs. For mobile applications, iOS apps were designed on the XCode 10. The Android apps were developed on Android studio. The mobile web app was developed using Hyper Test Mark-up Language (HTML) version 5 and cloud database were hosted on Google firebase. A Google QR code and a simple product barcode generator were utilised to create unique identifiers for each of the carcases involved in the study. The barcode generator program is an opensource free QR Code/barcode tool that is available as a google spreadsheet.

3.4.2.3 STEP 3: PILOT TESTING

The third step is pilot testing. In this stage, the researcher tested the equipment within the office premises of the participants to test the feasibility of implementation of the equipment or to identify any bugs with the program developed using the mobile of the participant. In general, the testing of each technology varied with the participants depending on the availability to test the functionality of the technology. The pilot ranged from between 1 week to 2weeks depending on the time and availability of participant to participate in the testing and use of the equipment or software. Following testing of each technology intervention, a specific date and time are arranged with each participant for the commencement of the intervention. After the testing of each technology, any other key staffs which will directly engage with such technology is trained on the capabilities, functionalities and use. The training was performed for 10 mins using two mobile phones for both Android and iOS devices. For hardware training, the training took between 10-15mins.

3.4.2.4 STEP 4: TECHNOLOGY DEPLOYMENT

The final technology deployment was conducted differently depending on the type and function of the intervention. For the mobile wireless and sensor technology interventions, the deployment was conducted onsite, and where necessary the mobile phone of the participants involved was also configured with the appropriate applications to facilitate communication and interactions between the sensors and the mobile devices of the user. This allowed each small business owner to remotely activity of the installations through the mobile phone app or an internet dashboard on a desktop computer that is equipped with a stable internet connection.

The sub-steps utilised for the mobile app technology intervention in the retail segment, are as follows.

- Sub-step 1*(identification of data elements)*: The research consulted with the butcher to identify unique data elements for meat provenance verification system. In terms of provenance, a number of unique data elements were utilised, and they include the type of red meat, barcode tag number, farm origin/ geographical origin, name of actors involved with the movement of the product (if known), date and time stamps, meat grade. However, participants were flexible in choosing data elements that correspond to the level of transparency which they want to provide to the consumer. The mobile app was developed with the flexibility to add more data elements as required by the participant

- Sub-step 2*(Advertisement of the app):* The researcher in consultation with the butcher the developed an advertisement sheet /flier to inform the consumers of the new butcher app available for download for both Android and iOS devices (see Appendix B). The advertisement is displayed on the Window of the butcher store between 3-4weeks. For each mobile application platform, a QR code was generated which, when scanned by consumers, will open the app store aligned to their mobile devices for app installation.
- Sub-step 3:(*Development of marketing line*): During the advertisement period, the researcher in consultation with the butchers also developed a product marketing tag line *"lamb of the week" and "beef of the week"* to raise consumer awareness of the possibilities to scan the QR code for the lamb or beef of the week to learn more about their traceability. A stand was placed in the store on the display cabinet that is open to consumers to view and order meat product. The butchers were encouraged to sensitise consumers regarding the role of the QR code and the app should there be any inquiries. Consumers who indicated an interest based on the advertisement were asked to either scan in-store or pick a card, download the app, and check the traceability of meat product either when they get to their homes. A sample of this card is shown in appendices (Appendix C)

The implementation of the mobile app was conducted in three parts. Part 1 was a hybrid web app deployed in the cloud via Google firebase, and this served as the traceability web-app timeline interface. Part 2 was a native mobile application that consumers could download and install on their devices by visiting the app store. Part 3 is the backend/database system to input data elements and to save the information for consumer verification.

3.4.3 PHASE 3: POST-INTERVENTION EVALUATION

In the post-intervention evaluation phase, participants who were involved in phase 1 and phase 2 were re-contacted to provide feedback on how and to what extent did the technology intervention impact their visibility and capacity for traceability in the challenges faced. The post-intervention also allowed for comparison of the quantitative impact of technology intervention of visibility in terms of improvement in some or all of the information quality criteria aligned to the traceability challenges.

3.4.3.1 SUB-STEP 1: DISCUSSION OF FINDINGS WITH CASE STUDY PARTICIPANTS

In this-step, each participant involved in the intervention were re-contacted to discuss the key findings from the technical data generated from the technologies deployed. The purpose is to understand how the participant perceives the results and to provide context for the data generated. This interaction will also allow for better analysis and interpretation of the data generated from the intervention. The key findings that emerged from this interaction are presented in Chapter 4 and interpreted in Chapter 5.

3.4.3.2 SUB-STEP 2: OBTAINING PARTICIPANT FEEDBACK

After the discussion of the results with the participant, the researcher then asks for their feedback on the perceived role and potential impact of the technology intervention on traceability and organisational operations. This feedback will enable the researcher to identify the criteria utilised by participants for evaluating the role and impact of the mobile technology interventions in traceability and organisational operations along the supply chain. This feedback will also illustrate the extent to which the intervention impacted traceability internally, externally and along the chain, and to identify whether areas of information and visibility were enhanced in the intervention process.

3.4.3.3 SUB-STEP 3: GENERATION AND PRESENTATION OF THE FINAL REPORT

After the feedback has been received from each participant, the dinings obtained from the entire study are prepared and submitted as a final report. As mentioned in the invitation form approved by the Research Ethics Committee of the University of Tasmania, each participant could download a copy of the report to gain insights into the key findings that emerged from the study. It is anticipated that the findings generated by this report submitted as the thesis will provide a basis for the participants to consider areas in their supply chains where the deploying low-cost mobile technologies can enhance visibility and capacity for traceability in critical areas of their supply chain. A crucial part of this report is the generation of a new small businesses traceability framework to identify how and where low-cost mobile technologies can be deployed most effectively in small business supply chains within the red meat industry to enhance traceability and respond to some of the critical challenges it faces in the chain.

3.5 RESEARCH DATA COLLECTION

Research data collection required the utilisation of techniques compatible with the research problems and research questions underpinning this study(Al Kilani et al. 2016). Within the IS discipline, the three most widely utilised data collection approach include qualitative, quantitative and mixed methods approach(Williamson 2002). Qualitative research methods explore a real-world phenomenon on the field or life situations that include subjective views or experiences, values, and behaviours in a given context. Qualitative data collection techniques include the use of interviews, observations, document analysis and focus groups discussions. Quantitative research methods are used where control of variables, randomisation, and valid and reliable measures are required and where generalizability from the sample to the population is the aim(Newman et al. 1998). Quantitative methods also fall under the category of empirical studies or statistical studies. Quantitative data collection technique includes surveys, field observations, document screening and experiments. The third approach is mixed methods, and this involves a combination of qualitative and quantitative research methods (Gable 1994). Mixed methods research combines theoretical and/or technical aspects of quantitative and qualitative research within a particular study(Rocco et al. 2003).

The value of combining research methods has received significant attention in IS research and has led to mixed methodologies (Gable 1994). Mixed methods research combines theoretical and technical aspects of quantitative and qualitative research within a particular study (Rocco et al. 2003). According to Palinkas et al. (2011), the use of mixed methods in implementation research provides immense benefits to the research in multiple ways. Firstly, it can be used to complement one another either simultaneously or sequentially for the purpose of :(a)answering the same question through convergence of results from different sources; (b) answering related questions in a complementary fashion; (c) using one set of methods to expand or explain the results obtained from use of the other set of methods; (d) using one set of methods to develop questionnaires or conceptual models that inform the use of the other set; (e) and using one set of methods to identify the sample for analysis using the other set of methods.

This research utilises a mixed-method research design to guide the collection of research data in multiple case studies. The research as selected a mixed-method because it aligns with the nature of inquiry of this study. In Phase 1 (Pre-intervention phase), this research aims to understand traceability challenges facing small businesses operating in a Tasmanian red meat supply chain, using three key steps namely: (a) industry familiarisation, supply chain mapping and baseline data collection. This would require the collection of qualitative and quantitative data from industry stakeholders and supply chain participants to aid the identification of potential traceability challenges in the chain and to contextualise these challenges at different points for potential intervention using low-cost mobile technologies.

In Phase 2 and 3, the research is also interested in understanding the role and potential impact of implementing low-cost technology for enhancing traceability by capturing qualitative impact (participant feedback) and quantitative impact (impact of technology in information quality and overall visibility).In applying a mixed-method approach, the key data collected was primary data. Additional data to complement the primary data was also collected during the study. The details of each data collection types are presented in the next section below.

3.5.1 PRIMARY DATA

Primary data are those data that are collected for the specific research problem at hand using procedures that fit the research problem context(Hox et al. 2005).In this study, primary data was collected from the following sources: *semi-structured interviews, field site visits, survey questionnaire, and technology experiments.*

3.5.1.1 SEMI-STRUCTURED INTERVIEWS

Interviews provide in-depth information about participants' experiences and viewpoints of a particular topic (Turner III 2010). Interviews are typically divided into three main formats, and they include:

a) Structured interviews- consisting of verbally administered questionnaires, in which a list of predetermined questions are asked, with little or no variation and with no scope for follow-up questions to responses that warrant further elaboration;

b) Unstructured interviews involving questions that are asked with little or no organisation; and

c) Semi-structured interview: which consist of several key questions that help to define the areas to be explored, but also allows the interviewer or interviewee to diverge in order to pursue an idea or response in more detail Gill et al. (2008).

This research adopts a semi-structured interview approach in the collection of primary data. This reason for utilising this method is because of its inherent flexibility in guiding to interviewee while following up with important questions in areas that can throw more light into the phenomenon being explored. Semi-structured interviews were conducted with both industry stakeholders and small businesses operating within the Tasmanian red meat industry. The interview followed a guide that was developed based on the objectives of this research, and this was used to aid a structured format for asking participants questions in a coherent and cohesive manner.

3.5.1.2 METHODS FOR CONDUCTING THE SEMI-STRUCTURED INTERVIEW

In conducting the semi-structured within the three-phased strategy, the researcher was inclined to use two methods, namely on-site face-to-face interviews and off-site telephone/skype interviews. On-site interviews were conducted within the premises of the participants to enable complementary data to be collected, such as pictures, documents, and observations. During the interview session, the researcher utilised a voice recorder app on an Apple mobile phone to capture the voice data during the interview. Off-site interviews are utilised for some participants due to geographical constraints, which made it impractical for face to face conversation. In this case, a skype/phone interview was scheduled, and the session was recorded on a mobile phone recorder app. Some participant were re-contacted for a follow-up interview in the course of this study to provided clarity in areas that were pertinent to the inquiry. Also, follow-up interviews were re-scheduled in circumstances where the initial interview was cancelled during the session due to changes in the business schedule. At the end of an interview session, the researcher replayed the recorded conversation and transcribed each interview to a transcript to identify areas for more clarification and further analysis. This approach provided the opportunity for the researcher to reflect on each interview.

3.5.1.2.1 PROFILE OF INTERVIEWED PARTICIPANTS IN PHASE 1(PRE-INTERVENTION

Semi-structured interviews were conducted in Phase 1-pre-intervention (industry familiarisation and supply chain mapping) and Phase 3- post-intervention evaluation phase respectively. In the pre-intervention, 18 participants were interviewed, comprising of 7 industry stakeholders and 11 supply chain actors. In the post-intervention, only 5 participants that agreed were interviewed for the post-intervention and evaluation phase. The next section describes the profile of interview participants that were interviewed.

3.5.1.2.1.1 INTERVIEW WITH INDUSTRY AND GOVERNMENT STAKEHOLDERS IN THE FAMILIARISATION STEP

In the industry familiarisation phase, 7 industry stakeholders were interviewed for this study. Table 5 below shows the participant profile for the industry stakeholders involved in the study. The stakeholders included 5 program managers from the DPIPWE covering, 1 liaison officer from the Hobart city council and 1 state representative from AMIC. These 7 participants provided sufficient insights that enabled the researcher to explore and familiarise with the critical traceability challenges facing Tasmanian small businesses in the red meat industry.

Table 5: Participant profile of the industry and government stakeholders interviewed for the study

	Industry agencies				
Traceability program	DPIPWE	FSC	AMIC	Position	ID
Biosecurity and Traceability	✓			Program Head	P01
Primary produce & Meat safety	✓			Program Head	P02
Agricultural and Veterinary chemicals (AgVet Chem)	✓			Program Head	P03
Animal brands	✓			Program Head	P04
Animal welfare	✓			Program Head	P05
Hobart city council (retail FSA inspection)			✓	Program Head.	P06
AMIC Tasmania		✓		State Rep	P07

The industry stakeholders were held top management positions in their respective fields in order to generate rich insights on the range of issues and challenges affecting traceability amongst small business owners in the Tasmania red meat industry. The protocol for the interview schedule with industry stakeholders can be found in the Appendix(Appendix D). The structure of the interviews are as follows: (a) describe traceability practices in the red meat supply chain; (b) provide insights into the current traceability challenges being faced by the industry as well as small businesses along the supply chains; (c) describe the current role of information technology, and (d) provide stakeholder experiences based their interactions with Tasmanians small business on the potential traceability challenges facing small businesses in terms of the factors that inhibit or enhance their capacity to utilise technologies in responding to the challenges. Each interview took between 60-90min per participants, and a follow-up interview was held in instances where further clarifications were required to shed more light in areas pertinent to the research.

3.5.1.2.1.2 INTERVIEW WITH CASE STUDY PARTICIPANTS IN THE SUPPLY CHAIN MAPPING STEP

In the supply chain mapping step, the researcher interviewed 11 participants operating at different segments of the red meat supply chain. Table 6 below shows the profile of the supply chain participants that were interviewed in the supply chain mapping step. The participants comprise of small business owners operating in the lamb and beef supply chain across the following segment farm production, cattle transport, stock agent, sale yard, wholesaler, cold chain transport, and retail butcher. The participants held top management positions that were limited to either the owner-managers of the firm or were senior operational staffs for the given firm. This ensured that only those with adequate knowledge of the research topic were interviewed.

Table 6: Number of supply chain participants interviewed in the supply chain mapping step

Supply chain operation	*Position*	*No of participant*	*Participant ID*
Cattle Farmer/Transport	Owner manager	1	P08
Lamb Farmer/Transport	Owner manager	1	P09
Saleyard	Saleyard operations A	1	P10
	Saleyard operations B	1	P11
Stock agent	Owner manager	1	P12

Meat processor	Owner manager	1	P13
Wholesale	Owner manager	1	P14
Retail butcher 1	Owner manager	1	P15
Cold chain/Retail butcher 2	Owner manager A	1	P16
	Owner manager B	1	P17
Retail butcher 3	Owner manager	1	P18
Total number of small businesses=9	**Total number of case study participants interviewed in supply chain mapping step=11**		

It is important to note that there were no fixed rules applied regarding the ideal number of interviewees in a given firm. For example, in the saleyard 2 participants were recruited because the firm determined that they could provide important information concerning the sale yard operations. In the cold chain retail butcher store 3, two participants were interviewed based on the decision of the small business owner. Each interview took between 60-90min per participant, and a follow-up interview was held in instances where further clarifications were required to shed more light in areas pertinent to the research

3.5.1.2.1.3 INTERVIEW WITH PARTICIPANTS IN THE POST-INTERVENTION EVALUATION

In the post-intervention evaluation phase, the same participants that were involved with the technology experiments were recontacted to provide their feedback concerning the role and potential impact of the intervention in their respective segments. Table 7 below shows the number of small business owners and participants that were interviewed in the post-intervention evaluation phase, and these include the cattle farmer (1 participant), retail butcher 1 (1 participant), meat processor (1 participant), retail butcher 2(1 participant), and retail butcher 3. The participants were the focal companies for the intervention. Each participant provided their perceptions concerning the role and potential impact of the technology intervention in traceability and organisational operations.

Table 7: Case study participants involved in the technology post-intervention evaluation

Foci of Technology intervention	*Position*	*No of participant*	*Participant ID*	*Focal*
Cattle Farmer/Transport	Owner manager	1	P08	Case study 1
Retail butcher 1	Owner manager	1	P15	Case study 2
Meat Processor	Owner	1	P13	Case

	manager			study 3
Cold chain/Retail butcher 2	Owner manager A	1	P16	Case study 3
Retail butcher 3	Owner manager	1	P18	Case study 4
Total number of small businesses=5	**Total number of case study participant interviewed in post-intervention=5**			

The interview with each participant took between 60-90min, and a follow-up interview was held in instances where further clarifications were required to shed more light in areas pertinent to the research. The interview schedule for the post-intervention can be found in the appendices (Appendix D). It focused on two key areas of participant feedback: (a) The perception of the participants concerning the role and potential impact of the technology intervention on traceability; (b) the criteria utilised for evaluating the technology intervention in their respective businesses.

3.5.1.3 SURVEY QUESTIONNAIRE

Questionnaire refers to documents that include a set of standardised questions, often called items, which follow a fixed scheme in order to collect individual data about one or more specific topics(Lavrakas 2008). Questionnaires are employed a variety of research to achieve multiple objectives, such as (a) profiling and descriptive research where the purpose is to generate a profile of characteristics of the sample; (b) predictive and analytical, where the purpose is to understand any relationships between variable; (c) developing and testing measurement scales where the purpose is to generate a measurement scale, or a set of statements to measure complex variables such as service quality, trust, or innovation(Rowley 2014). This study adopted a questionnaire from the work of Caridi et al. (2010) for assessing perceptions of the level of visibility and product impacting their supply chain segments. The details of the application of the survey questionnaire are presented in the next sub-section below.

3.5.1.3.1 MEASURING VISIBILITY AT EACH SEGMENT

The survey questionnaire proposed in this study is part of the heuristics framework adapted from the work of Caridi et al. (2010). The survey questionnaire measures visibility to traceability challenges using three information quality criteria, namely *accessibility, accuracy, and currency and freshness*. Table 8 below illustrates the

Table 8: **Judgement scale of visibility metrics for traceability information at each supply chain node (adapted from Caridi et al. (2010)**

Traceability information Freshness	Supply chain node (0)	I have access to none or less than 25% information (1)	I have access to at least between 25%-50% information (2)	I have access to at least 50- than 75% information (3)	I have access to at least than 75% or more information (4)
Traceability information Accuracy	Supply chain node	The accuracy of exchanged information is usually very low and unsatisfactory (1)	The accuracy of exchanged information is usually satisfactory but situations in which information is incorrect is not u common (2)	The accuracy of exchanged information is usually satisfactory which information in few situations (3)	The accuracy of exchanged information is usually satisfactory and very accurate (4)
Traceability information Completeness (Quantity)	Supply chain node	Information is not always updated and not satisfactory (1)	Information is only updated when I ask suppliers to provide data (2)	In some cases information is updated when the node is asked to provide data (3)	Information is updated in real time in most cases (4)

nature of the scales that the focal participants are asked to use in self-assessment of organisational visibility to key traceability information aligned to traceability challenges of meat provenance, meat safety, meat quality and animal welfare. Visibility levels were assessed using a quantitative scale adapted as follows: (a) Low: 0 -25%;)(b) Somewhat low to average: 25-50%; (c) Above average to excellent: (d) 50-75%; (e) and Excellent: > 75%. The criteria used for each are the accessibility to information, quality of the information and information completeness respectively: Important metrics for each of these measures can be identified in the literature (Zhang et al. 2017). For example, in the area of meat safety, the temperature is considered an important metric, especially in the cold chain from the processor to retail For provenance, important indicators include geographical positional systems (GPS) readouts at handovers points along the chain, country of origin/geographical labelling, and regional location labelling, as well as ingredients percentage labelling. In the area of meat quality, intrinsic and extrinsic indicators such as the pH, breed, sex, age, provide a useful measure of the quality of meat (Mach et al. 2008). In the area of animal welfare, studies have found the usefulness of collecting accelerometer and inertia data to validate the welfare status of cattle (Robert et al. 2009). In terms of animal welfare and meat quality combined, another area of increased significance is “halal meat” verification, and recent studies have found the usefulness of utilizing certification number to validate compliance to slaughtering procedure based on Islamic religious beliefs(Latif 2020).

3.5.1.3.2 PROCEDURE FOR QUESTIONNAIRE DISTRIBUTION

The procedure for questionnaires distribution was as follows. After the supply chain mapping exercise, the research held preliminary meetings with the small business owners in a given segment to identify and prioritise the critical traceability challenges faced by the businesses in the chain. A key focus in this phase is to solicit their engagement in the baseline data collection to enable the researcher to understand how they perceived their level of traceability and visibility of information in areas of meat provenance, meat safety, meat quality, and animal welfare. This approach would also support the identification of technology intervention points, where visibility may be limited but can be enhanced using low-cost mobile technologies. Table 9 below shows the number of participants that participated in the visibility assessment and filled the questionnaire. In total, 4 small business owners from different supply chain segments participant in the visibility assessment exercise. These comprise of 3 retail butchers and 1 farmer. The details of the visibility assessment conducted for each participant can be found in the analysis chapter (Chapter 4, Section 5-8).

Table 9: Case study participants involved with quantitative baseline data collection using a survey questionnaire

Foci participant	*Position*	*No of participant*	*Participant ID*	*Supply chain*
Cattle Farmer/Transport	Owner manager	1	P08	Case study 1
Retail butcher 1	Owner manager	1	P15	Case study 2
Cold chain/Retail butcher 2	Owner manager A	1	P16	Case study 3
Retail butcher 3	Owner manager	1	P18	Case study 4
Total number of small businesses=4	**Total number of foci survey questionnaire participants =4**			

During the assessments, the researcher was present to provide further clarity in definitions of terms used in the questionnaire.

3.5.2 ADDITIONAL DATA COLLECTION

3.5.2.1 DOCUMENT REVIEWS

In this study, the research obtained secondary data from documents related to traceability practices from both industry stakeholders and supply chain actors at different segments of the chain. According to O'Leary (2017), three main types of document can be obtained and analysed in the course of an inquiry, and these include: (a) Public Records: The official, ongoing records of an organisation’s activities. Examples include student transcripts, mission statements, annual reports, policy manuals, student handbooks, strategic plans, and syllabi; (b) Personal Documents: First-person accounts of an individual’s actions, experiences, and beliefs. Examples include calendars, e-mails, scrapbooks, blogs, Facebook posts, duty logs, incident reports, reflections/journals, and newspapers; (c) Physical Evidence: Physical objects found within the study setting (often called artefacts). Examples include flyers, posters, agendas, handbooks, and training materials.

In the industry familiarisation and supply chain mapping phase, the research relied on both public records from the internet, policy manuals, photographs of equipment on-site, handbooks and training manual to complement primary data obtained during the semi-structured interviews. In supply chain mapping phase, the research relied on secondary data from internet websites, photographs of equipment on-site, flyers, and paper labels to complement primary data captured in the field. In the technology intervention, secondary data included paper labels that carried data elements useful for the implementation of a traceability system along the red meat supply chain. No secondary data was captured in the post-intervention phase.

3.5.2.2 FIELD SITE VISITS

Multiple field site visits were conducted by the researcher to complement the research data obtained from the interviews. The conduct of the field visits required the research to organise an appointment with the owner-manager or operational staffs of the businesses aligned to the study, and then a date was agreed for site visits. The site visits provided a research context for describing the different range of operational activities linked to traceability of red meat internally and externally between firms in the chain.

3.6 DATA ANALYSIS

Data analysis involves the techniques and tools used in the analysis of data obtained during the research study. Since the study utilised a mixed-method design, the analytical approach made use of both qualitative and quantitative techniques. Qualitatively, the researcher utilised coding techniques to analyse interview transcripts and to facilitate the generate themes, and document analysis to analyse the additional documents obtained from industry and supply chain participants. Quantitatively, the analytical technique utilised included :(a) the mathematical formulae adapted from the work of Caridi et al. (2010) that converts Likert scale assessment to numerical scores; (b)statistical analysis linked from within the algorithm integrated into the sensor system; and (c)Apple and Google analytics® dashboard. The application of these analytical techniques is discussed in the next sub-section.

3.6.1 QUALITATIVE DATA ANALYSIS

3.6.1.1 THEMATIC ANALYSIS

Thematic analysis is a qualitative method for identifying, analysing, and reporting patterns (themes) within data(Braun et al. 2006). It involves the identification of themes through “careful reading and re-reading of the data” to identify patterns that are linked within the data (Fereday et al. 2006). In thematic analysis, two major approaches have been developed, and they include inductive and deductive “theoretical” thematic analysis. Inductive analysis is a process of coding the data without trying to fit it into a pre-existing coding frame, or the researcher’s analytic preconceptions(Braun et al. 2006). This form of thematic analysis is data-driven and the themes identified are strongly linked to data(Patton 1990). Theoretical‟ thematic analysis is the process of coding the data based on the researcher’s theoretical or analytic interest and is thus more explicitly analyst-driven(Braun et al. 2006).

This study utilised the deductive ‘theoretical’ thematic analysis procedure to guide the analysis of qualitative data collected from the field. The heuristics framework formed the basis of the theoretical contrast used to guide the study. Four pre-conceived themes are generated and utilised to guide the analysis of the interviews. These are meat provenance, meat safety, meat quality/authenticity, and animal welfare. The interview transcripts are coded under these themes, and the key findings that emerged are organised as core categories to provide a description of the theme. The aim of this approach is to contextualise each traceability challenges defined as key themes and identify input which can be utilised to refine, validate and generate a new framework based on research evidence from the field. In the context, the process of coding the data was organised to fit or refine the researcher pre-existing analytic preconceptions which is the heuristic framework. One of the important analytical tools required to conduct thematic analysis is coding. This is discussed in the next section.

3.6.1.2 CODING

Coding is the process of breaking down data, such as interviews or observations, into distinct units of meaning, which are labelled to generate concepts(Goulding 1998). It is a grounded theory approach that uses a systematically applied set of methods to generate an inductive theory about a substantive area (Glaser et al. 2009). Three types of coding are involved in the grounded theory technique, namely: open coding, axial codes, and selective coding(Kendall 1999). Open codes are the first level coding that breaks down data into distinct concepts, headings, and categories. Axial coding explores the relationships between emerging categories. This coding technique makes sure that all the important aspects within data have been identified and assigned to an appropriate category. Selective coding leads to the eventual development of the core categories, which will be representative of all emerging categories. A fundamental feature of grounded theory is the application of the 'constant' comparative method(Goulding 2000). This feature involves comparing emerging codes within data to identify emerging patterns and themes during the course of the coding process. In this study, the example of the application of the coding technique is shown in the Appendices (Appendix E). It shows a sample data that is being used to illustrate the steps the researcher took to analyse each interview transcript, generate codes and assign the codes to categories before discussion and interpretation of results.

In step 1, tentative categories related to focus of the interview were defined, and these relate to challenges of traceability facing small businesses in their supply chain and the extent to which they relate to issues of *meat safety, meat provenance, meat quality/authenticity, and animal welfare*. In this example, The participant described a critical issue related to the inability to gain visibility to information and material flows in the red meat supply chain from sale yard to final processing and post-processing. Based on this analysis of the statement, four lines of the statement were identified and were grouped in before the coding process. Here the researcher read the interview transcripts line by line and utilised to highlight those statements that seemed relevant to the tentative categories in what became the first iteration of open codes.

In step 2, the categories were compared to one another to identify relationships between the open codes, and this led to the generation of new categories called axial codes. Here the common denominator amongst the statement highlighted is visibility and capacity for the whole of chain traceability across batch operations and processing, meat safety, animal handling and transportation, and the whole of animal lifecycle traceability. In step 3, each of the newly generated categories was selected and compared to the tentative categories in step 1 (i.e. meat safety, meat provenance, meat quality, and meat authenticity), to determine their relationships. It is based on the categorisation of axial codes that selected codes were determined. Here the selected codes that illustrate the participant’s views regarding perceived traceability challenges faced relates to issues of meat safety and animal welfare. Based on this selected codes, the participant’s statements, opinions and quotes were taken out and presented as part of the findings from the interviews. Each category was arranged under the key themes of this study, namely meat provenance, meat safety, animal welfare, and meat quality.

It is not uncommon to find instances where the contents within a selected code did not fit into existing categories. In such instances, new categories were developed. Also, there were cases in which some categories were complementary to core categories, and in such context, participants statements were quoted directly. Other statements that could not fit directly into a category were summarised and paraphrased in the researchers own words. It is also important to mention that during the data analysis, some categories exhibited strong relationships in meaning, e.g. traceability issues aligned with meat quality, meat authenticity and provenance can be used interchangeably by the participant and as such the context of the transcript determines the selected code and category for discussing the given statement. This merging of codes eliminated redundancy in categories and quotes. After the coding process was concluded, the findings from the interviews, along with the collected quotes, are presented in chapter 4. In chapter 5, each of the categories that emerged from the themes is interpreted and discussed in the context of research literature (see Chapter 5).

3.6.2 QUALITATIVE CONTENT ANALYSIS

Qualitative context analysis (QCA) can be defined as the subjective interpretation of the content of text data through the systematic classification process of coding and identifying themes or patterns(Hsieh et al. 2005). Within this investigation, text data may include verbal, print, or electronic form, and print media such as articles, books, or manuals within the organisation. The researcher utilised QCA to analyse and extract essential data elements from documents, receipts, invoices and manual, and the outcome was the identification and selection key data elements that were utilised in the implementation of the mobile meat verification app in the butcher store. The procedure for conducting QCA included: (a) Step 1: Collection and reading all data from manuals, forms, and electronic media that provide additional information on traceability (i.e. information and material flow alignment) between actors along the red meat supply chain from farm to retail. This phase provides the researcher with the means of obtaining a sense of the whole document and data elements useful to each process involved in red meat supply chain operations; (b) Step 2: Reading word for word for each document to derive codes by highlighting exacts words from the text that seem to capture key concepts. These concepts were validated by discussing with the participants that provided the documents; and (c) Step 3: Arrangement of codes into major themes, categories, and case examples for discussion and interpretation of findings (Chapter 4-9).

3.6.3 QUANTITATIVE DATA ANALYSIS

Quantitative analytical approaches allow the reporting of summary results in numerical terms(Abeyasekera 2005). Three quantities analytical techniques were adopted in the study, and they include the mathematical model/formulae adapted from the work of (Caridi et al. 2010), descriptive statistical analysis from Google analytics and iOS Developer Account linked to the mobile web and native applications, and mathematical algorithm developed integrated with the sensors for analysing tri-axial accelerometer readings generated from cow activity sensors. The discussion of each technique is presented below.

3.6.3.1 MATHEMATICAL MODEL FROM THE HEURISTICS FRAMEWORK

Quantitative data obtained from the survey questionnaire was analysed using the mathematical formulae adapted from the work of (Caridi et al. 2010). Table 10 below illustrates the mathematical formulae used to convert Likert scale score to a numerical score for each of the information quality criteria. It shows the formulae for calculating node and total visibility to traceability challenges faced by a focal firm in their supply chain segment. The assessment of visibility is calculated for the three information quality criteria, namely completeness, freshness and currency, accuracy. Finally, a total visibility score for each traceability challenge was calculated as the cube root of quality (accuracy and freshness) and amount(quantity) (accessibility) of visible information in a supply chain segment.: Visibility levels were assessed using a quantitative scale adapted as follows: (a) Low: 0 -25%;)(b) Somewhat low to average: 25-50%; (c) Above average to excellent: (d) 50-75%; (e) and Excellent: > 75%.

Table 10: Assessment of information quality metrics for visibility of information at each supply chain node (adapted from Caridi et al. (2010))

Indicator	Formula
Completeness/Quantity of overall visible information	Node_visibility_completeness k= $^4\sqrt{}$ tc,s* tc,q* tc,p*tc,w
Accuracy of the overall visible information	Node_visibility_freshnessk= $^4\sqrt{}$ta,s* ta,q* ta,p* ta,w
Freshness of the overall visible information	Node_visibility_freshnessk= $^4\sqrt{}$ tf,s* tf,q* tf,p* tf,w
Overall visibility for a given type i information at a node k	Node_partial_visibilityi,k= $^3\sqrt{}$ tc,s* ta,s tf,s
Quality of the overall visible information	Node_visibility_qualityk=√ Node_visibility_accuracyk * Node_visibility_freshnessk

3.6.3.2 MATHEMATICAL MODEL FOR ANALYSIS OVI-BOVI TRI-AXIAL ACCELEROMETER DATA

The wireless activity tag utilised in this study is embedded with an NFC chip and a programmable three-axis microelectromechanical (MEM)accelerometer which captures accelerometer readings in three-axis a_x, a_y and a_z[40]. Inside the tag, the MEMS sensors output pedometric reading in the following: a_{x_i}, a_{y_i} and a_{z_i} values at ith measurement (i = 1, 2, 3, 4, ...), at the sampling rate of 1.5Hz. These three bytes of data are sent to the microcontroller, which is then vectorised into two consecutive measurements, using the analytical formulae: sqrt((ax2-ax1)^2 + (ay2-ay1)^2 + (az2-az1)^2). Finally, an internal algorithm developed by Ovi-Bovi[41] is used to analyse the vectorised measurement into x and y and axis, where x=activity metric, and y=dates. The final data is presented in a mobile web compatible dashboard with a trend line chart showing a calculated score of activity(y-axis) for each monitored cattle tagged with the sensors, and date/time duration (x-axis).

3.6.3.3 DESCRIPTIVE ANALYSIS

Descriptive statistical analysis involves the analysis, interpretation, and presentation of numerical data in tables or graphs (Stanley 2007; Thompson 2009). In this study, quantitative data obtained from sensors, mobile and native applications were analysed and presented in statistical graphs and line plots. In addition to this, descriptive-analytical data was also obtained from different analytical tools utilised

[40] https://www.st.com/content/st_com/en/products/nfc/st25-nfc-rfid-tags-readers/st25-dynamic-nfc-tags/m24lr-series-dynamic-nfc-tags/m24lr04e-r.html

[41] https://ovi-bovi.com/files/tag-reprogramming-with-NFC-manual-en.pdf

in the conduct of this research and these include google analytics, google developer account, Apple developer dashboard.

3.7 DATA INTERPRETATION AND DISCUSSION

This refers to the approach utilised for discussing and interpreting the findings obtained from the data analysis. In the data interpretation phase and interpretation phase, the research examines the significance of the findings that emerged from the analysis of qualitative and quantitative presented in (Chapter 5) and discusses their significance using the research literature. The interpreting and discussing the key significant findings from the analysis chapter (Chapter 4), the research utilises the three-phased approach, namely: **Phase 1**-Pre-intervention (Step 1:Industry familiarisation, Step 2:Supply chain mapping, Step 3: Baseline data collection); **Phase 2**- Technology intervention; and **Phase 3-** post-intervention evaluation. A key activity engaged in during the discussing is to refer back to back to the literature review chapter (Chapter 3) to identify similarities and differences in findings from other author and to identify where new knowledge has emerged from this study as part of the contribution of this work to the body of knowledge. The outcome is the generation of new insights that can shed more light into understanding the traceability challenges impacting small businesses at different segments, and the role and potential impact of utilising low-cost mobile technologies.

3.7.1 RELIABILITY AND VALIDITY CONSIDERATIONS

The research utilised a case study methodology and acknowledges that one of the limitations of this approach is the issue of reliability concerning natural generalisation of findings (Johnson et al. 2004). Reliability refers to the extent to which studies can be replicated to obtain the same results achieved by prior studies. Validity is characterised by the extent to which the research instrument achieves the intended measure (Wise et al. 2019). Although the measure of reliability and validity are linked to a positivist epistemology, they are useful instruments that can be utilised to enhance utilises from qualitative research (Golafshani 2003).

Reliability of findings is examined both internally and externally. Internal reliability refers to the consistency of results within a particular site and the credibility of data within that site. External reliability refers to the consistency and duplicative attributes of data across the sites (Neuman, 1994). However, in qualitative research, measuring the reliability of findings can be difficult because most qualitative studies often occur in natural settings where the researcher has no control of the processes in the environment. This means that even the most exact replication of methods can fail to replicate identical results. This is because, for most qualitative studies, accurately reconstructing the natural setting in which the prior study was conducted is extremely difficult.

However, to enhance the reliability of findings, multiple measures were taken to enhance the reliability and validity of instruments used in the study. Internal reliability was enhanced by using low-interference descriptors such as field notes and interpretive comments that were documented during the field exercise. This measure ensured that the researcher was providing a reliable context in which the study was conducted. Also, the research confirmed the responses provided by the interviewee by using corroborative evidence obtained through field observation, documentation, and field photographs in the study site. Externally reliability was enhanced by taking into consideration the appropriate informant choices, social situations and conditions, analytic constructs and premises, and methods of data collection and analysis.

Firstly, the research limited informant choices to owner-managers, operations managers and in the case of industry stakeholders all identified themselves as program heads for their respective agencies/departments. This approach ensured that only knowledgeable participants were recruited and interviewed for the study and that their responses reflect their experiences from having operated in the industry as professionals.

Secondly, the social situation in which the research is conducted was taken into consideration in enhancing the reliability of findings. For example, where the researcher faced challenges with recruitment of participants, gathering field data, or conducting experiments in the field, the research documented those challenges and presented them as part of the limitations of the study.

Thirdly, in terms of the analytic constructs and premises that underpinned this study, the research utilises a heuristics framework to explore and to understand traceability challenges amongst small businesses in the red meat supply chain and the role and potential impact of implementing low-cost mobile technologies for responding to some of those challenges. In this context, the framework utilises three information quality metrics that are common with the definition and conceptualisation of visibility and traceability. These metrics include accessibility, accuracy, and freshness and currency. While there are multiple information criteria that can be used to explore traceability and visibility, the research has selected these three as the most significant in this study based on research literature. Given the interpretive nature of this study, the research is inclined to also presents results from participants views and perceptions regarding traceability and visibility challenges. The industry stakeholders and supply chain participants may hold divergent views regarding these concepts. Where the understanding and definition of these concepts are divergent, the researcher ahs pointed out the ambiguities in the interpretation and discussion chapter with quotes referenced to remove ambiguity in the definition of terms.

Fourthly, in terms of the method of data collection and analysis, this research has provided a description of the research data collection strategies used to guide this exploratory research across the three-phases. This study has also utilised a questionnaire survey to obtain baseline data on the level of visibility to potential traceability challenges facing the focal participant selected in the supply chain segment. The questionnaire is an adaptation of the work of Caridi et al. (2010).To improve reliability, the measurement variables in this research were adapted to fit into the research context of this study. Given that the instrument has been validated with the authors' results published (Caridi et al. 2013), the researcher was inclined to utilise the framework as a heuristic tool to: (a) Test and to explore the applicability of the framework in assisting with identification of points for technology intervention, and (b)Support the generation of a new refined framework based on new evidence gathered from this study. To maximise the reliability of the questionnaire, the researcher utilised a number measures which included: (1) familiarising participants with measurement parameters such as the information quality metrics and allowing participants to prioritise the traceability challenges based on their businesses needs; (2) framing the question succinctly to reduce ambiguity in terms being measured and also to minimize bias in order to enhance the statistical value of the data; and (3) ensuring that only recruited participants (mainly owner-managers or top operational managers) were allowed to fill the questionnaire. The face validity of the instrument was also vetted by the researcher’s supervisors during the study, and they were helpful in enhancing the wordings of the questionnaire. The outcome is a revised questionnaire which is presented to the participants in their premises.

3.8 RESEARCH ETHICS

This research and its methodological approach were approved by the University of Tasmania Social Sciences Human Research Ethics Committee (HREF) Ref No: H0016911 (Appendix A). The project falls within the Minimal Risks study in accordance with HREF requirements which includes disclosing to prospective participants the objectives, risks and benefits of the project. The attachment of the advertisement sheet, consent form and invitation letters can be found in the appendices(see Appendix A). The researcher was listed as the primary investigator for this study and was the contact point between the research and the prospective participants.

3.9 CHAPTER SUMMARY

This section provides a summary of the methodology chapter. The chapter has presented the philosophical underpinning that will be used to answering the research questions and achieve the key objectives of this exploratory. The research takes an interpretivist and subjectivity philosophical position for this study. The research strategy makes use of a multiple case study of small business operating within the Tasmanian red meat industry. The research design utilises a three-phased approach to guide data collection across pre-intervention, technology intervention and post-intervention and evaluation phases. The research methods involve the use of a mixed methodological approach to guide data collection, analysis, and interpretation. Mixed methods can help to enhance the reliability of findings in qualitative case study research, and this study aims to leverage its versatility to generate rich data for analysis and interpretation. In the next chapters (chapter 4-8), the analysis of findings from having applied the proposed methodological approach is presented.

Chapter 4

Analysis of Findings: Phase 1 (Industry familiarisation and Supply chain mapping)

4.1 INTRODUCTION

This chapter presents the findings that emerged from the Phase 1 (industry familiariasation and supply chain mapping exercise) The aim of this chapter is two-fold; Firstly, it presents the key findings that emerged from interactions with industry and government stakeholders in the pre-intervention phase(industry familiarisation step) on potential traceability challenges facing Tasmanian small businesses at different points along the red meat supply chain. Secondly, it presents preliminary findings that emerged from the supply chain mapping exercise conducted to identify and select supply chain partners that will participate in this study. The breakdown of the section of the analysis chapter is as follows: **Section 4.2** presents the key findings that emerged from the pre-intervention phase (*Step 1-industry familiarisation).* A total of 7 industry stakeholders were interviewed to provide their inputs concerning critical traceability challenges facing Tasmanian small businesses at different points of the red meat supply chain from a regulatory and government perspective. **Section 4.3** presents the analysis of key findings that emerged from the pre-intervention phase (*Step 2-supply chain mapping exercise).* It includes preliminary findings from the recruitment and selection of case study participants, and the organisation into case studies for further analysis. **Section 4.4** summarises the key findings from this chapter.

4.2 PRE-INTERVENTION PHASE

As described in the research design section of the methodology chapter (Section 3.4), the pre-intervention phase involves three key steps, and these are: (a) industry familiarisation; (b) supply chain mapping; and (c) baseline data collection. A total of 18 semi-structured interviews were conducted in this phase, and these comprise of 7 interviews with industry stakeholders and 11 interviews with supply chain actors in the red meat supply chain. The next section presents the analysis of findings from step 1-industry familiarisation with 7 industry stakeholders.

4.2.1 STEP1: INDUSTRY FAMILIARISATION

The research interviewed 7 industry, and government stakeholders were interviewed in this step, and they include 5 participants from the DPIPWE, 1 participant from Hobart

City council/FSC, and 1 participant from AMIC. The purpose of the interview was to understand some of critical traceability challenges potentially impacting Tasmanian small businesses in their supply chains. The discussion with these stakeholders focused on four major themes: meat provenance, meat safety, meat quality/authenticity, and animal welfare. All participants were allowed to provide sector-specific guidance and input regarding these challenges based on their core expertise and experiences with small businesses along the supply chain. The core categories that emerged under each theme is presented in the next section below.

4.2.1.1 MEAT PROVENANCE

The core categories that emerged under the theme of meat provenance include *compliance, transparency and proof of meat origin, and identity preservation*. The next sections presented the key findings from each of the categories that emerged.

4.2.1.1.1 COMPLIANCE

In the area of compliance, three sub-categories emerged in relation to the potential traceability challenges affecting Tasmanian small businesses in their supply chains. . The traceability challenges related to meat provenance is described by one participant in the context of the extent to which firms have the capacity to comply with minimum legislative requirements of red meat traceability. In discussing issues of provenance, one participant mentions the role of meat processor in the following statement.

> *"So it's a national requirement that a processor is able to trace a product one step backwards, one step forward so that if there's ever a problem with a product that's unsafe or unsuitable, they can recall that product from, from either their customer or they can send the product back to their supplier". (Participant P02)*

Another participant stated that compliance to minimum requirements on meat provenance in the red meat supply chain is linked to the degree to which businesses are able to share timely information on the traceability of the cattle from farm production to final slaughter. The participant believes the capacity for meat provenance is therefore linked to the **timeliness of traceability information** sharing along the supply chain through the NLIS.

> *"Legislations prescribes that they have got to receive certain information about their movement and they have also got to give off certain information, and they have got to upload that information to NLIS database a certain timeframe. So, we keep the regulatory view over that and similarly for processor once they receive cattle, and they are processing they have got to decease those cattle as dead on the NLIS database, and they have got to do that within a prescribe timeframe". (Participant P01)*

In discussing the issue of compliance, one participant believed that small hubby farmers are exposed to **risks of non-compliance**, and this is linked to their **limited understanding and awareness** concerning traceability obligations.

> *"Cattle farmers because their cattle are worth pound for pound more, yeah, they are pretty good with compliance. Sheep farmers, they are fairly compliant although they are a bit harder sometimes with the tagging requirements cos you know there is less value on a sheep. Pig farmers you know, it is the backyard producers for pigs, so they are not spot on. However, it is just, small farms they do not understand some of the reasons for having traceability and hard to get to understand and get them to fulfil the obligation, and some of them know".(Participant 01).*

Poor supply chain co-ordination

This perceived vulnerability to compliance risks was also confirmed by another participant in terms of their limited capacity to meet minimum information-sharing requirements in order to maintain traceability and transparency of the supply chain. This participant believes part of the problem with hubby farmers is **lack of proper supply chain coordination** and **limited knowledge** concerning mandatory and voluntary traceability obligations critical to traceability of the beef.

> *"Um, another issue they have a lot in understanding all the systems because they get the pic number and registered for tags with us. They get the tags from another source; then they get their vendor dec from another source and then if they have another accreditation with the sale yards or ever tools like this, never never programs that side of things. Um, they are not sure where to go to for a lot of those. We try and provide as much as we can when we send out the information". (Participant P04)*

Poor organisational attitude and limited understanding

Another participant also confirmed the issue of limited traceability understanding and the impact this could potentially have on their ability to meet compliance obligations to enhance the provenance of red meat along the supply chain. This participant links this issue of compliance to ***poor organisational attitude towards the role and importance of IT in traceability.***

> *"A lot of hobby farmers probably do not realise their obligations. They probably are a harder bunch to connect with. For instance, they do not know they are going to put an ear tag in at the farm and once it leaves the property. So, some of the hobby farmers and small-scale producers are too difficult, to get to make them understand why they're going to make their NLIS requirements and legislative requirements but some of the bigger producers, you know, it's a business, and they've got to know, and they do it" (Participant P01).*

The same participant believed that hubby farmer exhibit **poor attitude** towards the importance of traceability, and this opens up vulnerabilities in their capacity for provenance along the red meat supply chain.

> *"It has been a sort of lackadaisical approach to it where people have just forgotten about why we do traceability. The export people know cos the market demands it, but in domestic some people start to be like " why are we tagging these animals? We are only going up here. They just do not appreciate that If you do not do traceability you can get tripped up by not having trivial bits of information and time and you know, one farmer not doing things can affect a traceback" (Participant P01)*

Supply chain fragmentation

However, this issue of compliance linked with meat provenance has also been suggested to be as a result of the ***fragmentation of the Tasmanian red meat supply chain***. This fragmentation, it was gathered, inhibits the flow of information and knowledge amongst actors in the chain and limits industry engagement with supply chain actors operating in the chain.

> *"At some stages It is fragmented. Another stage is not. So the pic side of things, it is just sometimes getting the communication out there to the small farmers is a bigger issue in Tasmania than the big farmers who know it and the knowledge come on down through the families. But the smaller farmers and there are a lot of small farms in Tasmania and a lot of hobby farmers that it is*

> *harder to get the information out to and get the right information at the start for them." (Participant P04)*

Another participant believes that the problem of traceability related to provenance amongst small businesses can be linked to a ***poor harmonisation of traceability standards*** legislated at different points in the chain. It is also believed this inability to harmonise traceability standards and data elements linked to meat provenance has led to uncertainty concerning the extent to which businesses have to provide information to meet the minimum traceability requirements

> *"At the moment there are just so many different programs, and they are not sure what they have to have and what is extra to them. And that sometimes can be an issue. They sometimes get told one thing by the agents, and oh no, you need to get the NVD, but you know, you've purchased some animals for the first time and they are told that well, you need an NVD or you need tags and the person you know instead of persons starting at the beginning and contacting the department and getting the whole process, they get quite confused and which makes it very difficult at times". (Participant P01)*

External socio-technical factors

There were indications from some participants that the issue of compliance to ascertaining meat provenance in the chain can also be linked to external ***socio-technical factors and barriers*** *such as limited access to internet connectivity, equipment malfunction and failure, and low digital literacy in the industry*. In terms of the issue of internet connectivity, one participant has this to say:

> *"Especially with vendor declaration side of things because they actually can't get online and do their accreditation, that can be quite hard. We try and help with giving them the phone number to actually call and get the information sent out to them so then they can call back and do their registration on the phone". (Participant P04)*

Amongst the key issues mentioned, the same participant believed that limited ***internet connectivity*** can be linked to ***geographical location, and topographic terrain*** where these smallholder farmers reside

> *"And so there are a few issues like with the computer side of it now. There are a lot more technology and the farmers that are in bad areas because it's so many mountains and different things here in Tasmania. There's a lot of blind spots when it*

> *comes to [connectivity] and it makes it difficult for them to get access to the internet". (Participant P04).*

The same participant also stated that the inability for some red meat small businesses to meet compliance requirements to ensure transparency and capacity for provenance in the chain is also due to ***poor literacy skills*** in the use of technology. The participant believes that amongst some local farmers, many still have limited digital literacy skills required to meet up with changing requires in red meat traceability that requires the use of technologies in the chain

> *And we often too have people that come in that have, um, limited literacy skills, so we'll sit down and help them work through and do their registrations and set things up so that they're right and they've got a good understanding and make sure they've got an understanding of what's needed". (Participant P04)*

4.2.1.1.2 IDENTITY PRESERVATION

The category of identity preservation relates to beliefs held by industry stakeholders concerning the **inability of small businesses to preserve the identity of meat along the supply chain**. One participant stated this problem in the following

> *"So, um, so for a processor, if, um, you know, there are 100 cattle come through, there might be 10 that, that during their lifetime, have lost lifetime traceability because someone did not upload the information and so we look at the sender (Participant P01)*

The same participant links the issue of identity preservation to issues related to **equipment malfunction**, lost RFID tags or lack of animal registration during birth.

> *"There are tags that don't scan for whatever reason or there are ones get pulled out or there are ones that obviously don't have tags and we just got to try and work out what cattle were they fall in". (Participant P01)*

4.2.1.1.3 TRANSPARENCY AND PROOF OF MEAT ORIGIN

Some participants believe that issues of meat provenance are also linked *to* ***poor transparency, limited visibility, and poor information sharing***. In terms of transparency, one participant mentioned the issue of poor records management.

> *"I will say their record-keeping, and they could improve on their record keeping. I have had cases for the use of certain*

> *information. They are not even making their records."(Participant P03).*

In terms of **information sharing**, another participant stated the following.

> *"Farmers hate sharing information".(Participant P05)*

Another participant links the issues of meat provenance **to poor visibility, limited supply chain knowledge, and the influence of third-party agents**.

> *"With some butchers the things, the ones that actually purchase the meat and send it straight to the abattoirs and then back to themselves usually have a fairly good idea of where their meat comes from. It is the smaller butcher that would have someone from the abattoirs that actually purchases the animals for the men, sends them to the abattoirs, and then they come back to them - they probably do not have a higher knowledge of what they have not actually gone and picked out what they are wanting and yeah. So in that line, some of them, you know, it is sort of would be harder to, to trace and to know." (Participant P04)*

4.2.1.2 MEAT AUTHENTICITY

One category emerged in relation to potential traceability challenges of meat authenticity, namely ***issues of meat substitution and labelling***.

4.2.1.2.1 ISSUES OF MEAT SUBSTITUTION AND LABELLING

One participant believed that traceability challenges related to meat *authenticity can be linked to* ***issues of substitution and labelling***. In a case mentioned concerning meat sausages, the participant mentioned that issues of provenance amongst some retailer butchers are underpinned by **poor product differentiation, the possibility of co-mingling, lack of transparency, and improper labelling of the compositional attributes** used to produce value-added meat products sold to consumers.

> *"We specifically targeted sausage a few years ago because there was a thought that what people were putting in sausages and what they were calling them weren't the same. So if you were saying this is a beef sausage, but it is 98 per cent whatever, then they cannot call it a beef sausage because it is not a beef sausage". (Participant P06).*

4.2.1.3 MEAT SAFETY

Three participants with expertise in the area of meat safety volunteered to provide their experience concerning the traceability challenges impacting small businesses in their supply chains. The core categories that emerged are the ***risk of chemical residue detection, risk of heavy metal contamination, and risk of microbial contamination***. These core categories are presented in the next section.

4.2.1.3.1 RISK OF CHEMICAL RESIDUE DETECTION

One participant stated that possibilities of chemical residue detection amongst small businesses, especially local farmers, along Tasmanian red meat supply chains are not uncommon. The participant stated that this possibility is linked to ***non-compliance with mandatory withholding period for animals*** treated with veterinary chemicals or the lack of transparency regarding the use of veterinary inputs on animals sold to the sale yard or directly to the meat processors. Although it was gathered that the while frequency of occurs is low, the possibilities do exist because there have been cases where residue detection have occurred in the supply chain.

> *"We might only get 1 or 2 detections a year. In the last year, 2 to 3 a year but it is not many. The risk is that If any residue is received overseas. It might have a detrimental impact on the industry because it depends on the market where it goes to and they might say we don't want any more Australian beef. This is the extreme end though". (Participant P04).*

The same participant considers the farm production segment to be **the most vulnerable to risks of chemical residue detection**. However, it was also stated that system and technologies for traceback of the source of the detection exist, using the NLIS and NVD reports generated for each animal processed.

> *"The residues that we pick wouldn't be anything further than the abattoir and so we will know in most cases, with beef, we will know what animal that was, and what property it came from and we will be able to trace back using the national livestock identification system (NLIS) number of the cattle to trace back to the property. We will know from the NVD what property the animals came from because all animals have individual devices on their ear and would hopefully know where the animals came from and if it has moved from one property to another property". (Participant P04)*

4.2.1.3.2 HEAVY METAL CONTAMINATION

One participant believed that exposure to heavy metal contamination poses significant traceability challenges to many small businesses due to their poor agricultural practices.

One particular case of lead (Pb) metal contamination in the farm was mentioned and this contamination incident was linked to **improper incineration of batteries.**

> *"We also get into heavy metal contaminants, uh, for example, if animals are exposed to lead, so you get a lead poisoning situation, then we have a system where the animals are actually quarantined for life. Um, and you know, unless they actually test them to show that they have completely free of lead, they are quarantined, and they could possibly go through total slaughter for human consumption or all the offal have to be condemned. In one case, the animals that have been exposed to lead were found to come from old abandoned batteries or something like that you might find these". (Participant P05).*

The same participant then added the following:

> *"I mean there are Lead tracebacks that have happened from time to time. Um, but then once you, so once you detect the problem that whole property sort of affected and assigned a lead status. So The cattle on that property are managed, and the system allows them to manage that well. Um, there are more incidents on the mainland". (Participant P05)*

4.2.1.3.3 MICROBIAL CONTAMINATION

Some participants believed that microbial meat contamination poses a significant traceability challenge for small businesses due to ***poor processing conditions, hygiene, or cross-contamination during slaughter operations***. One participant stated that cases of microbial meat contamination are known to occur in the meat processing phase

> *"Human health risk is not a lot of diseases like Salmonella is and things like that you tend to pick up at Slaughter due to contamination, right? Salmonella is present in the gut normally. And if you've got a poor slaughter, you'll get salmonella (Participant P05)".*

Another participant confirms the possibility of meat contamination and suggests that the cold logistics chain could also be exposed to these risks. The participant links this possibility to **poor hygiene and temperature abuse during transportation**.

> *"So all we are looking at the transport businesses is with the maintaining temperature control and whether the inside of the trucks is clean and well maintained and that the drivers have basic hygiene skills and knowledge. So they know when to wash their hands, you know, how to handle the meat and so forth. So it does not become contaminated (Participant P02)"*

Another participant believes that small businesses face **challenges of poor transparency of information** on meat temperature along the cold chain, and this could limit the capacity to ascertain the safety of the meat purchased from the abattoir. The participant further stated that **fear of opportunistic behaviour and accountability** on the part of the cold chain operators could be contributing factors limited traceability of meat safety in the cold logistics chain.

> *"Some of them might be nervous about, you know, if it is going on a truck and then the temperature spikes or something goes wrong, that can happen everywhere in any way. You are going to have issues, and nothing runs smoothly. You might have a breakdown, things like that but having that traceability, if it can be tagged and they can see where it is coming and how long it is in a yard before it went through the Abattoir, how long was hanging up in the fridge? Getting that temperature down. Um..i thinks its good. Yeah. Maybe the abattoir is thinking I do not want us to look at that technology because they might have issues. You know. They are a bit nervous about it, but it is a chance also to maybe fix-up problems. You know". (Participant P07)*

4.2.1.4 ANIMAL WELFARE

One participant with expertise in animal welfare provided input regarding the potential traceability challenges related to animal welfare amongst small businesses in the Tasmanian red meat supply chain. Two sub-categories emerged, and these are ***poor scheduling and poor visibility of*** *truck operations.*

4.2.1.4.1 POOR SCHEDULING

The participant believes the key challenge of animal welfare in the Tasmanian red meat supply chain relates to *problems of scheduling and lack of visibility in animal handling and care operations during road transportation:*

> *"The truck will go and pick up calves from a number of farms. A little truck will go and pick them up from a number of farms, taken back to the depot and then they will be put onto a bigger truck. So they might go and pick up calves from a dozen farms. When they picked him up to the farm, and they picked him up from a crate at the gate basically. So they might not even see the farmer, they do not know how long the calves have been in the crane". (Participant P05).*

4.2.1.4.2 POOR VISIBILITY OF TRUCK OPERATIONS

The same participant further stated that this issue of scheduling and lack of visibility exposes the meat to risks of loss in meat quality

> *"Uh, you know, poor animal it produces a better product anyway and then something been stressed and malnourished or being forced around busy the, you know, the animal is stressed, it becomes tight, the meat itself will actually go darker, and it doesn't always result as a good product to eat because the acid levels and everything is high".(Participant P05)*

4.2.2 SUMMARY OF FINDINGS

This section has presented the analysis of findings from the interactions with industry and government stakeholders concerning potential traceability challenges impacting Tasmanian small businesses in their supply chains concerning meat provenance, meat safety, meat quality/authenticity, and animal welfare. A total of 7 stakeholders provided inputs regarding these issues. The research found that the potential traceability challenges impacting meat provenance relate to issues of compliance, identity preservation, and Transparency and proof of meat origin. The traceability challenges related to meat quality relates to meat substitution and labelling. The traceability challenge related to meat safety relates to the *risk of chemical residue detection, microbial contamination and heavy metal contamination*. The traceability challenge related to animal welfare was found to be linked to issues of scheduling and lack of visibility in animal care and handling operations.

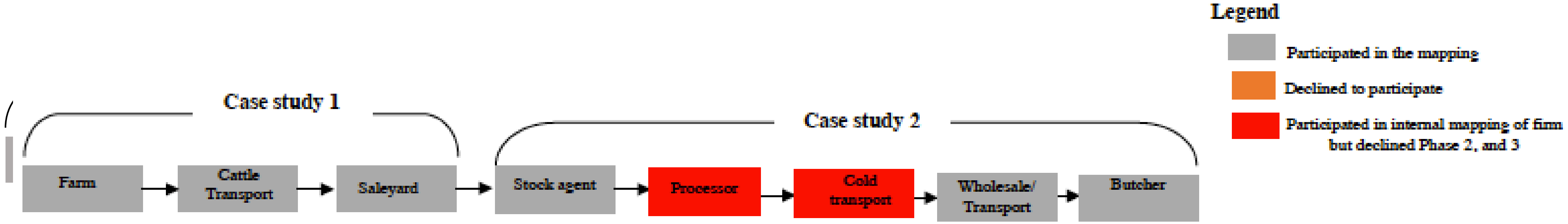
4.3 PRELIMINARY FINDINGS FROM STEP 2-SUPPLY CHAIN MAPPING

4.3.1 PRELIMINARY FINDINGS FROM THE RECRUITMENT AND SELECTION OF CASE STUDY PARTICIPANTS

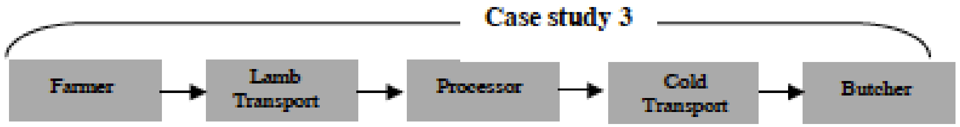
As discussed in the methodology chapter (Chapter 3, section 3.4.1.4.2), the supply chain mapping exercise began with preliminary recruitment of 4 local retail meat butchers to serve as focal companies. The goal was to utilise the information from the butcher to identify the list of actors in their respective supply chains and to facilitate their invitation and recruitment for the mapping exercise. However, one butcher later dropped out of this study and reduced the number of focal participants (i.e. butcher) to 3.

Figure 11 below shows the supply chain map of the four local retail butcher supply chains that were initially invited to participate in this study. As seen in Figure 11 below,a total of 23 participants drawn from different segments of the chain were invited, and these include *farmers, road transport, sale yard, stock agent, meat processor, wholesaler, cold chain transport, and retail butchers*.Some butchers supply butcher purchased live cattle meat directly from the saleyard and through a stock agent. Others purchased processed meat directly from the processor. As shown in

Figure 11 below, the fourth butcher along with the farmer initially agreed to participate in the study but later withdrew during the course of the supply chain mapping exercise.As a result, the entire case study was cancelled. Reasons for this decline in participation include lack of interests, perceived privacy infringement, and tight business schedules.



A: Supply chain map for retail butcher 1 showing the number of businesses that participated in the mapping exercise



B: Supply chain map for retail butcher 2 aligned to a lamb chain with actors that participated

C: Supply chain map for retail butcher 3 showing the number of businesses that participated, declined or initially participated and later declined.

D: Supply chain map for retail butcher 4 showing the number of businesses that participated, declined or initially participated and

Figure 11: Supply chain map showing the number of businesses that participated, declined or initially participated and later declined participation in the study

The profile of the case study participants involved in this exploratory research is presented below in Table 11. It shows that the case study participants held positions that comprised of owner-managers, sole business owners, while others were senior operational staffs in their firms. The organisation of the case study across multiple red meat supply chains are as follows: **Case study 1**: This is a fragmented beef supply chain focused on the pre-slaughter segment and comprised of three participants, namely: 1 cattle farmer/transport (P08), and 2 saleyard operations participants (participant P10 & P11); **Case study 2:** This is the fragmented post-slaughter segment of the beef supply chain that is linked to case study 1 through the saleyard. Three participants are involved in this case namely: stock agent (P12), Wholesale (P14), and retail butcher 1 (P15);**Case study 3:** This is a lamb supply chain that comprises of all actors, namely: lamb farmer/transport (P09), Meat processor (P13), cold chain/retail butcher (P16 & P17); and **Case study 4:** This is a retail butcher store operating within a beef supply chain, and comprise of only one participant -the owner-manager of the retail store (P10) was recruited in this case study.

Table 11: Profile of case study participants involved in this exploratory study

Supply chain operation	*Position*	*No of participant*	*Participant ID*
Cattle Farmer/Transport	Owner manager	1	P08
Lamb Farmer/Transport	Owner manager	1	P09
Saleyard	Saleyard operations A	1	P10
	Saleyard operations B	1	P11
Stock agent	Owner manager	1	P12
Meat processor	Owner manager	1	P13
Wholesale	Owner manager	1	P14
Retail butcher 1	Owner manager	1	P15
Cold chain/Retail butcher 2	Joint owner-manager A	1	P16
	Joint owner-manager B	1	P17
Retail butcher 3	Owner manager	1	P18
Total number of small businesses=9	**Total number of case study participants interviewed in supply chain mapping=11**		

The next 4 chapters (Chapter 5-8) presents the analysis of the key findings for the 4 case studies that include Pre-intervention -step 2 (supply chain mapping), step 3 (baseline data collection); Phase 3 (technology intervention); and Phase 3 (Post-intervention evaluation).

4.4 SUMMARY

This chapter has presented the key findings from the industry familiarisation phase and preliminary findings from the supply chain mapping exercise. In the industry familiairsation, the research interviewed 7 government stakeholders to understand potential traceability challenges impacting Tasmanian red meat supply chains. The government stakeholders revealed multiple traceability challenges impacting Tasmanian small businesses in their supply chains in relation to issues of provenance, meat safety, meat quality, and animal welfare. Some of the most critical challenges related to traceability were found to includes issues of compliance, identity preservation, and transparency of production, and proof of meat origin. Some governemtn stakeholders also believed that Tasmanian small busineses could be exposed to risks of meat safety such as *chemical residue detection, microbial contamination and heavy metal contamination*. In the supply chain mapping phase, preliminary findings revealed significant difficulties in the recruitment and selection of industry participants for the case study. A total of 23 participants were invited to participate in the study, and these include farmers, road transport, sale yard, stock agent, meat processor, wholesaler, cold chain transport, and retail butchers. However, only 9 participants from 7 businesses agreed to participate in the study across the three phases. Based on these findings, four case studies were selected and explored using the three-phased approach. The analysis of findings are presented in the next 4 chapters.

Chapter 5

Analysis of Findings: Case study 1

5.1 INTRODUCTION

This chapter presents the findings that emerged from the analysis of field data for case study 1, a preslaughter beef supply chain segment operating within the Tasmanian red meat industry. This chapter aims to explore traceability challenges faced by small businesses operating in the pre-slaughter segment of the beef chain and to understand the role and potential impact of deploying low-cost mobile technologies for responding to the critical challenges faced. Each section is structured using the three-phased strategy to provide answers to the research questions, and these are pre-intervention (supply chain mapping and baseline data collection), technology intervention, and post-intervention and evaluation. The breakdown of the section of the analysis chapter is as follows. **Section 5.2** presents an overview of the key findings that emerged from case study 1. **Section 5.3** presents the analysis of key findings that emerged from **Phase 1-Pre-intervention** (supply chain mapping and baseline data collection). Section 5.4 presents the analysis of findings from **Phase 2-(technology intervention)**. The key findings from **Phase 1 and Phase 2** will provide answers to **Research Question 1**: *How can low-cost mobile technologies be utilised and deployed amongst small businesses in red meat supply chains to support traceability and for responding to challenges faced?* Section 5.5 presents the analysis of findings from **Phase 3-Post-intervention evaluation**. The key findings from **Phase 3** will provide answers to **research question 2**: (a)*What criteria do small businesses in red meat supply chains use in evaluating the role and potential impact of low-cost mobile technologies in supporting traceability and for responding to challenges faced*?; (b) and **research questions 3**: How *can a small business traceability framework be developed to support the implementation and evaluation of low-cost mobile technologies to support traceability and for responding to challenges faced?* **Section 5.6** summarises the findings from the chapter.

5.2 OVERVIEW OF KEY FINDINGS FROM CASE STUDY 1

This section presents an overview of key findings for Case study 1, a pre-slaughter segment of a Tasmanian beef chain. As presented in Chapter 4 (see Section 4.3,

Figure 11), Case study 1 is linked to case study 2 (i.e. wholesaler, stock agent, and retail butcher) and both segments constitute a Tasmanian beef supply chain.

2 small businesses were interviewed in Case study 1 segment, and they include the farmer/ road transport, and sale yard operations. The participants include 1 farmer/cattle transport (P08) operator and 2 participants at the sale yard (Participants P10 & P11). In step 2- supply chain mapping, 3 participants were interviewed. After the mapping exercise, each participant was contacted to discuss the traceability challenges faced in their organisational operations and to obtain feedback concerning their willingness to explore areas where low-cost mobile technologies can assist in responding to some of these challenges. This discussion is required for each participant to ascertain if they will progress to step 3 (baseline data collection); phase 2 (technology intervention) and Phase 3 (Post-intervention). However, only the farmer agreed to progress further in the study. Thus the analysis of findings in baseline data collection step (step 3); Phase 2 (technology intervention); and Phase 3 (post-intervention) focuses on the farm. The next section presents the analysis of findings from the supply chain mapping exercise for case study 1, starting with the farm and then followed by the saleyard operations. The following key findings emerged from case study 1:

1) Phase 1 -Pre-intervention (Supply chain mapping step): Amongst the traceability challenges explored in this case study (i.e. meat provenance, meat safety, meat quality, and animal welfare), the supply chain participants believed the most significant were related to issues of animal welfare, and this was related to behavioural monitoring and oestrus detection in the farm production phase of the chain. Due to the lack of perceived traceability challenges in the saleyard operations, both participants interviewed declined to progress further in the study, i.e. Phase 2 and Phase 3, and as a result, the focus of this case study was on the farmer. Quantitative baseline data assessment showed that the farmer perceives a high level of visibility to potential traceability challenges related to issues of animal welfare with a visibility score of 3 out of 5.

2) Phase 2 (Technology intervention): In response to the perceived traceability challenges faced in the farm, the research deployed a low-cost cow behavioural monitoring sensing system in the farm to enhance visibility and for responding to challenges of animal welfare in the farm. The technology

faced multiple technical difficulties, including issues of poor internet connectivity and animal temperament that significantly impacted the useability and applicability of the system on the farm.

3) Phase 3 (Post-intervention): The farmer did not perceive any significant new role and potential impact of the technology intervention on traceability for responding to issues of animal welfare (i.e. behavioural monitoring and oestrus detection in the farm) due to small business size and lack of business fit. Also, the farmer believed that the technology intervention deployed in the farm could impact negatively on farm operations in terms of information overload and lack of commercial benefit

The next section below presents a detailed analysis of the key findings from Case study 1.

5.3 PRE-INTERVENTION (SUPPLY CHAIN MAPPING)

5.3.1 FARM

The farmer (participant P08) is a hubby farmer engaged in the production of beef and sheep meat. The farm is located in Campania, Tasmania. This mapping exercise focused on exploring traceability challenges in the farm in relation to the beef cattle. Two main cattle breeds are produced in the farm, and these include Angus and Hereford breeds. The supply chain map of organisational traceability practices for the farm is presented in appendices (See Appendix F). The description of organisational traceability practices across three levels, namely operations, technologies, and information, is presented in the next section below.

5.3.1.1 OPERATIONS

At the operational level, the key activities include growing new calves, grazing/feeding of livestock's, veterinary care, and soil management. In the growing phase, cows are raised to be mated by bulls during their reproductive cycle. The focus of farm producer is on expanding the number of heads in the farm through proper monitoring of oestrus cycle to detect heat and oestrus. In the grazing phase, all cattle are fed mixed hay and forage, and this is supplemented with green pastures that are naturally grown in the farm. Soil management includes the application of fertiliser inputs to soil, mainly grain and chicken manure, planting new paddocks, digging new trenches and running irrigation along the field. Veterinary activities include drenching of the herd once every six months to fight against any parasites that may have been picked up from the soil and the pastures during grazing activities.

> *"So at the moment where I'm. Yeah, basically ripping up all those paddocks. So keeping the fences intact but just ploughing up the paddocks. Um, we are fertilizing with grain fertiliser but also matured chicken manure, so that it puts some nutrients back into the ground. Uh, we used lime, so doing a whole lot of different things and then letting that sit for a while and cultivating it, uh, and then running a new seed in the ground" (Participant P08).*

In the transportation phase, the farmer is engaged in activities such as mustering and load-in, transportation and unloading of the cattle at the sale yard. Before loading transport, the livestock is fed and provided with drinking water to minimise panic and stress associated with mustering each cattle unto a truck. The participant also stated that motivation for engaging in road transport was to minimise stress in road transport that could result from exposure to unfamiliar persons or animals which could irritate the animals and cause abrupt behaviours or loss in meat quality.

> *"Um, but to me, it also stresses the meat. Um, and so I want to make sure that I'm always presenting the best quality animal at all times. And moving the cow on the back of a truck is a stressful thing. So we try to do is just do everything calmly and quietly, so if we muster, so the day we muster them, you know, we're not on the motorbikes revving them up, and we're just taking it all nice and quiet and slow and they get used to that too" (Participant P08).*

Other motivations for engaging in animal transport includes maintaining family traditions, enhancing the experience of children and due to the small size of cattle herds in the farm.

> *"To be honest with you, it is actually just the experience. We just enjoy taking the kids. I might, if a sale on a weekday, we might just put one or two of the kids out of school for it and they love it. They go have fun, and they are driving the truck, and it is just an experience. I think it is just a great experience. I think if I was to run big numbers of cattle and my farm was thousands of acres would be totally easier just to have to muster the cattle and then give the livestock carrier a call, and you can just pick up however many, take him to the job done. But when you already talking smaller numbers, I think it's just a, it's just more enjoyable to see them, you know, to see him grow on our farm, to then take them to the Sale yard to then sell them to then take your check home sort of thing, just the whole experience. I just think it is much more enjoyable". (Participant P08).*

5.3.1.2 TECHNOLOGIES

Two main IT tools are identified in the farm as having a relationship to traceability and these include mobile phones and RFID aligned with NLIS. The mobile technology is used primarily to facilitate communication with suppliers, schedule delivery of cattle to the saleyard and in communicating with other actors in the chain such as stock agent, veterinary doctors etc. NLIS is primarily used for animal identification as part of the compliance for individual tagging of livestock in the farm. The participant stated the ease with which new NLIS tags can be obtained for identification and registration of cattle on the farm.

> *"It's actually so I don't know whats it's like in the mainland, but, or other parts of the world. With Tassie, it is very easy. So if you've got them all ear-tagged and that is, so that's a matter of just going to one of your um a lot like rural stockers so we use xxx a lot" (Participant P08).*

However, the participant also stated that technology interactions with the NLIS system are limited, and this is partly due to the preference for a third-party agent for managing transaction of cattle in the chain.

> *"I've only actually spoken to NLIS once, and that was when I registered. Everything else happens now between the agents. So the agents might send them a mail to NLIS saying XXX name with NLIS number of ABC has sold 10 Angus and these were their numbers. So it could be my NLIS number 01, NLIS number 02 three, four, five all the way to 10. If I sold 10 and they were my first 10, it will be 48, 58 or whatever they. They list the number because every cattle is given, not just the NLIS number but then the actual property number. And then that gets updated with NLIS, and so yeah, the dealings with them are very easy". (Participant P08)*

5.3.1.3 INFORMATION

Four main components of information are captured, and they include PIC, RFID tag number, and transactional information within the NVD such breed of animal, sex, age, name of the farmer, address of farm, name of the transporter, name of the receiver, i.e. saleyard. These data elements are captured in paper-based forms. In facilitating a livestock transaction, the participant stated that the stock agent at the sale yard is utilised in activities such updating the NLIS database to notify of a transaction using the RFID tag number and PIC number.

> *"So the agents might send them a mail to NLIS saying xxxx with NLIS number of. I can't remember that. But then sold 10 Angus and these were their numbers. So it could be my NLIS number 01,NLIS number 02 three, four, five*

> *all the way to 10. If I sold 10 and they were my first 10, it will be 48, 58 or whatever they. They list the number because every cattle is given, not just the NLIS number but then the actual property number". (Participant P08)*

5.3.1.4 POTENTIAL TRACEABILITY CHALLENGES IN THE FARM PRODUCTION OPERATIONS

The interview in this section focused on understanding the potential traceability challenges impacting the farm production operations and the role of IT. The core categories relate to issues of meat provenance to meat *provenance*, *meat safety*, *meat quality, and animal welfare*.

5.3.1.4.1 MEAT PROVENANCE

Two sub-categories emerged concerning the farmer's perceived potential traceability challenges of meat provenance. These include **perceived compliance and organisational attitude.**

5.3.1.4.1.1 PERCEIVED COMPLIANCE

The farmer stated that he does not perceive any traceability challenge with ascertaining the provenance of the cattle. In his opinion, all his cattle are uniquely tagged in the farm, and as a result, their provenance could be ascertained through NLIS at any point in the chain. The farmer does believe individual animal identification is only required when the animals are being transported from one property to the another.

> *"So we don't need to notify them when they hit [are born] the ground [i.e the calves]. We just need to notify the NLIS if I was to go and sell them. So I've got to tag them all for sure. Absolutely. Put the ear tags. We do all of that. But um, that's only really important though when you go to sell them. If I was to not sell anything. So all the calves that hit the ground, if I was to just keep them for this, for my own personal use, I actually don't need to tag them. It's only for tracking where that was coming from. So if they leave my property, yes, they need to know who's cow is this, where they come from. Um, and that's what the ear tags show and obviously the registration with NLIS". (Participant P08)*

5.3.1.4.1.2 ORGANISATIONAL ATTITUDE

The participant also did not perceive any potential traceability challenge with not meeting tagging requirements for young calves at birth. He believes that as long the animals only need to be tagged when they are being transported to another property or before they leave the premises.

> *"So whether you do it when the calves are born or whether you do it when you are loading them up, it does not really matter, but you just ear tag them before they leave the property, which you get the tags from xxx or yyyy and that has got your NLIS number on it. Um, and then you do not even need to notify". (Participant P08)*

5.3.1.4.2 MEAT SAFETY

One sub-category emerged related to the participant's perception of traceability challenges of meat safety, namely low-risk perception to meat safety crises.

5.3.1.4.2.1 LOW-RISKS PERCEPTION OF MEAT SAFETY CRISES

The participant stated that he did not perceive any traceability challenge with meat safety because there has never been a case of a meat safety crises with regards to cattle sent to the sale yard.

> *"I've never had an issue. Obviously, if there was a sickly cow or whatever, they might ask some questions about what's going on it. But I've never personally had that. I've never taken cattle to a sale yard was 100 per cent strong. They looked good and had a good score." (Participant P08)*

The participant believed that it is unlikely for an animal with enhanced animal welfare conditions in the farm to be found to be infected with a disease or unsafe for consumption after purchase.

> *"And rarely do you get to a point where if your cattle are full of life walking around, very rarely would you have a case where there's a kind of moment and it's full of worms. Um, that would be pretty rare because you would know by the look of it, you could tell by the way it's holding itself, by the way it's reacting in the farm, you know, stockyard, whatever that you say this is wrong with these cattle. So rarely do they go through to the, to the butcher's and butcher knows what he's looking for too. So he's got an agent or whether the butcher himself- he's at the sale yards buying or his representative is They look at the stock and go coats are shiny, good frame, go through their score mentally and go there. This is good". (Participant P08)*

5.3.1.4.3 ANIMAL WELFARE

Two sub-categories emerged related to the participant's perception of traceability challenges of animal welfare, namely **perceived confidence in visual behavioural monitoring and perceived precision and accuracy of visual observation information.**

5.3.1.4.3.1 PERCEIVED CONFIDENCE IN VISUAL BEHAVIOURAL MONITORING

The participant stated that he does not perceive any potential challenge with ascertaining the welfare status of the animals on the farm because he can utilise visual behavioural monitoring to detect any changes in behaviours.

> *"Um, and you will find some of, some of them, if they are really on heat, they might walk up and down the fence lines wanting to get out, trying to find some fun, trying to find a mate or do something. But um, that is, that is your key indicator".(Participant P08)*

5.3.1.4.3.2 PERCEIVED PRECISION AND ACCURACY OF UTILISING VISUAL OBSERVATION INFORMATION

The farmer also believes that the information generated from visual observation is precise in detecting changes in the animal activity and that it can be used as a proxy for ascertaining the reproductive status of the cow. In the participant's view, visual monitoring techniques are more effective than the use of artificial insemination.

> *"Which is a lot higher than like artificial insemination, which can only guarantee for 50 per cent. So if you have a herd of 100, they're only going to guarantee 50 of them. Having a bull in the paddock for a period of time and letting them just do their thing. It's way higher. So out of like 100%, you're talking 70-80%".(Participant P08)*

The farmer does not perceive any traceability challenges with animal welfare monitoring because of the belief that that information generated from visual observation technique is accurate in terms of the reproductive performance achieved using the method in the farm.

> *"Um, and if you start looking at some of them, you'll notice that there are others are starting to form and some of them are carrying themselves differently. There's one in particular that we'll probably have another one either today or tomorrow. She's separating yourself from the herd, walking slower. Uh, she's got a massive girth on her, and so she's all ready to give birth to one. Um, so that'll make five. There are a few others that we can tell are already carrying t So there's not a wide will be 100 per cent. Yeah. Um, it never, it never is, but we're going to have a fair few will be well over 50%."(Participant P08)*

5.3.2 SALEYARD

The sale yard company in this study operates within the pre-slaughter segment of the beef supply chain and is linked to the cattle farmer in this segment (i.e. participant P08). Two participants (P10 and P11) working as sale yard operations administrators were interviewed. The supply chain map of organisational traceability practices for the saleyard is presented in appendices (See Appendix F). The description of organisational traceability practices across three levels, namely operations, technologies, and information is presented in the next section below.

5.3.2.1 OPERATIONS

At the level of operations, the sale yard performs 9 core activities from procurement of livestock from farmer to auctions sales and provision of carcase feedback information back to the farmer. These activities are: (a) booking and scheduling of livestock for auction; (b) transportation and animal registration at the sale yard using NVD documents; (c) weighing of livestock; (d) Physical fitness assessment and classification to pens; (e), generation of performance reports for buyer information; (f) branding of livestock for auction identification; (g)live auctions auction and sales; and (h) and load-in to transport operator for despatch to destination; (i) carcase feedback and pricing.

The first phase is the booking and scheduling of livestock. This phase involves direct contact with between the livestock agents and the farmer(client) to advise on upcoming auctions in order to prepare available stocks for despatch to the sale yard. The sale yard administrator visits the farmer to assess the cattle and to ascertain its fitness for transportation. Once the farmer agrees on the specific auction date, the saleyard administrator arranges for cattle transport to pick up the cattle at the farm address.

> *"A farmer will ring out and say I want to, uh, I want to market a portion of my livestock and then we will go down there and we will sort them out and we will arrange transport and then we call him back and let him know what the arrangement is". (Participant P10)*

However, scheduling of transportation for cattle is impacted by multiple factors which include time, availability of space in the truck, economic status of the farmer, and the temperament of the cattle. These factors can be opportunistic, in this case, the farmer takes advantage of free spaces in a truck to transport some cattle to the saleyard more due to the cost of renting a full truck.

> *"You know if there's a truck driver coming up, well it's, you could have four different vendors of stock on the truck. So if you know trucks going up, you say " oh crap I'll try and get mine on as well because it can be, can be expensive to get the truck for your own stock or it could just be, you know, I can't get down there for*

> *another week so you've got to wait another week or two".(Participant P10).*

However, the participant also stated that scheduling of cattle could be impacted by other factors. One participant describes these factors in the following

> *"Factors could be seasonal, It could be the farmer requires money i.e. Financial. It could be that the livestock doesn't suit the property. It could be the time of the year. It could be transportation, so if he only had three, three beef to go and the truck holds 50, but there was 47 on the track one day, then he's just got to suck eggs and, and uh, because it's economical for him to send them when there's room for three on that track than send the whole truck with only animals on it when they are ready, so it could be effective at, you know, that you've got to send them when, when the carriers going, not necessarily when the stock is in ideal situation because she can go the other way. Like you can have them that they too light or not in good enough condition, then you're going to have them over conditions which are just as bad". (Participant P10)*

The second step is transportation. The sub-operations performed in this phase, and they include load-in, transport, and unloading at the sale yard. Load-in operation is conducted by the transporters where animals are moved into their respective sections within the truck and then the doors are closed in order to begin the transportation to the sale yard. It was gathered that scheduling and pickup of cattle by the carriers are dependent on how it fits into the current schedule of the carrier and whether there is enough space to pick up additional livestock from other farms. Due to cost, the farmers and livestock agents do not contract carriers to pick up from a single farm except if the number of stocks can fill the truck. The livestock agent provided this illustration.

> *"Well, livestock carriers have their own clients the same as I have my own clients. Generally, a carrier will have a load to carry his livestock unless there's other stuff going and you need to fill a truck at that time. So you just to go Willy Nilly, down to pick up someone's cows because then you're, you're upsetting the livestock carrier" (Participant P10).*

Once the livestock has arrived at the sale yard, they are unloaded from the truck, weighed and ear tags are scanned to retrieve and update the NLIS database about the movement of the cattle. The third phase is the assessment phase. Experienced sale yard staffs conduct a preliminary evaluation of the physical and mental fitness of the cattle/sheep prior to weighing and registration to the property. The fourth phase is assessment. The staffs evaluate the body condition of each cattle to determine their classification and scoring. Critical evaluation criteria include body weight, temperament, and the overall fat cover of the animal. These criteria are visually observed and used to generate a quality score for each cattle. In the fifth phase, based on the score, the animals are classified into pens and prepared for auction. In the sixth, seventh and eighth phase, a performance report is generated for each animal and prepared for auction. The auction phase involved bidding sessions organised by the firm and this attended by prospective buyers and stock agents. Two auction services are offered in the complex, and they include *store sales and prime sales*. According to the one participant (P11), the store sales are auctions that are specifically designed for cattle that will go to another property such as fattening yard or another farm. The prime sales are designed for butchers and restaurants and other meat buyers who purchase live cattle for slaughter at the abattoir. The prospective buyers bid for the cattle which they perceive to be of high quality based on the amount of traceability information that is generated by the sale yard staffs and also received from the farmer before the auction. In the bidding process, the highest bidder pays for the cattle and change of ownership is performed in the sale yard by filling/updating new NVD forms. In the ninth phase, the buyer arranges for the transportation of the cattle to the final destination. The cattle that go straight to the abattoir receive a feedback sheet which is returned to the sale yard. The farmer is informed of the performance criteria for what constitutes a perfect carcase and price paid based on existing market price.

> *So we get a sheet back that says, uh, it gives us all the credentials on the cattle, and tells us what happened and which ones will and which ones didn't make it. And all the rest of it. And the price is according to that. And then we tell the farmer, this is what you got for your stock (P10).*

The key traceability information criteria used to assess the performance of a carcase includes *dead weight, dark cutting, fat colour*. These meat quality parameters are used to determine the final price of the carcase that will be paid to the farmer.

> *"So if they do not weight to meet weight specs, they go down 20 per cent. If they get dark, they go down a dollar a kilo. So you know like there might have been $5.40 for a steer to get for that, sees the optimum price and then there are all these factors which will cut the cents per kilo back".(Participant P10)*

5.3.2.2 TECHNOLOGIES

Within the sale yard, a number of IT tools are utilised to support the operation of the firm and to maintain traceability of each cattle entering into the property. Key technologies include RFID reader/antenna, desktop computer, digital weight bridge, mobile phone, and wireless Internet. The RFID reader is used to scan the RFID chip on the cattle and indicates on the computer screen the identification number of the cattle, and the vendor's PIC number. The desktop computer is used to fill the forms NVD forms accompanying the cattle which is uploaded over the internet to NLIS database. One participant describes the role of technologies in the traceability of cattle within the saleyard operations as follows.

> *"So this here, these are our scanners, so the cattle run through here [the weighbridge (in front of the weigh office)]. So these link up (ping off) to the NLIS system and give us our tag. So they come off the trucks, they'll come down here and get classed into whatever the fellows think that they should be. And then they'll run through here, so here we stamp them with a number to identify them, so a lot number that's a paint there. So they'll come up to the scales, we'll weigh them {on the weigh scales]. and then they'll run through the scanners down there and that'll give us their tag numbers in their ear. So every cattle has tags, the electric tags" (Participant P11)*

Emails are used to forward and receive electronic information such as scanned copies of the NVD, follow-up conversations with the stock agent or any other enquiries that may require extensive description. In terms of the role of email, the participant.

> *We do a lot more emails now so all our butchers might receive the actual type of copy. They will receive the scanned paper on email. And so we're transitioning a lot more into email. We're getting more and more clients on eft payments, more and more clients to receive invoices by email only and statements". (Participant P11)*

5.3.2.3 INFORMATION

At the level of information, the NVD is considered the most critical document that is utilised to ascertain the traceability of the cattle. A sample of the NVD document obtained is shown in the Appendices (Appendix G). In this document, the sale yard captures the RFID tag number, PIC of the farmer, name of the transport operator, name of the buyer, and associated animal veterinary input information such as the use of chemicals. The format in which is information presented and shared in paper forms. The sale yard also receives feedback information sheet from the meat processor. The key data elements generated in the feedback sheet include dead carcase weight, fat colour, and body condition score. Another critical information received by the saleyard is accreditation certificate which ascertains that the farmers have adhered to specific farm production practices in raising their cattle.

> *"The only information we receive is from the vendor declaration. Sometimes they will put in extra forms like never ever forms, accreditation, JBS farm assurance accreditation. Anything like they have like that they'll send into us as well and we'll always send a copy of that out with the purchase, and also would to the butchers via email or if it's a farm they'll get a copy as well in the mail as email. Yeah, yeah, yeah, yeah. So everything we received, the information about it, the purchaser will receive as well but just uh, it is just a scanned copy". (Participant P11)*

5.3.2.4 POTENTIAL TRACEABILITY CHALLENGES IN THE SALEYARD OPERATIONS

The interview in this section focused on understanding the potential traceability challenges impacting the saleyard operations and the current role of IT. Four core categories of traceability challenges emerged, and they are related to *meat provenance, meat safety, meat quality, and animal welfare.* The key findings that emerged from these core categories are presented in the next section.

5.3.2.4.1 MEAT SAFETY

Two sub-categories related to potential traceability challenges of meat safety emerged from the interaction with participants, and they **are perceived compliance to meat safety regulations and perceive low-risk likelihood of a meat safety crises**.

5.3.2.4.1.1 PERCEIVED COMPLIANCE TO MEAT SAFETY REGULATIONS

Both participants did not perceive any traceability challenges with meat safety because all information related to the production of the cattle are accessible through the NVD.

> *"Yes. Um., they will give us, um, I can show you that it's called a vendor declaration. National vendors declaration so that have on there the name of the owner, it will have Yes, I have owned them since birth. Um..No, I have not to feed them any grain or antibiotics. I think it was about eight questions, but I can show you one over there".(Participant P10).*

5.3.2.4.1.2 PERCEIVED LOW-RISK LIKELIHOOD OF MEAT SAFETY CRISES

One participant believed that the likelihood of a meat safety issue in the saleyard is low. However, in his opinion should any carcase be determined to be unsafe for consumption by the meat processor. This certificate, it was mentioned, follows the cattle back to the farmer from where it was grown.

> *"um, if there's a problem with it, we can get what's called a condemnation certificates from the butcher. That's just if, if there was a problem inside (the body) and the meat wasn't good".(Participant P10)*

5.3.2.4.2 MEAT PROVENANCE

Both participants did not perceive any traceability challenge with provenance. Two sub-categories emerged in relation to the lack of perceived potential traceability challenges in the area of meat provenance and they are **perceived compliance to animal identification and registration, and perceived ability to ascertain traceability of red meat.**

5.3.2.4.2.1 PERCEIVED COMPLIANCE TO ANIMAL IDENTIFICATION AND MEAT PROVENANCE

Both participants did not perceive any traceability challenge with provenance. One participant stated that both manual and electronic traceability methods of animal identification and registration have been implemented in the saleyard to preserve the identity of each cattle.

> *"So the scans will come in and the cattle run through, we weigh them, so this is our sheets. So when we weigh them, we paint them with a lot number. So we will have a lot of 10 can be two heifers. The scales will tell us what they weigh, their full weight, their average, we put in the vendor who they are. We brand them again with another paint marks so like two dots or no mark or on the pins or the back. And that just helps us to identify the candidate in the pen". (Participant P10)*

5.3.2.4.2.2 PERCEIVED ABILITY TO ASCERTAIN TRACEABILITY OF CATTLE

Another participant believed that the information NVD is sufficient to ascertain the provenance of each cattle sent to the saleyard.

> *"The only information we receive is from the vendor declaration. Sometimes they will put in extra forms like never ever forms, accreditation, JBS farm assurance accreditation and so on. Anything like they have like that they will send into us as well and we will always send a copy of that out with the purchase and would to the butchers via email or if it is a farm they will get a copy as well in the mail like email. Yeah, yeah,*

> *yeah, yeah. So everything we received, the information about it, the purchaser will receive as well, it is just a scanned copy". (Participant P11)*

5.3.2.4.3 MEAT QUALITY AND AUTHENTICITY

Both participants did not perceive any challenge with ascertaining the authenticity of beef cattle delivered to the saleyard. Two sub-categories related to potential traceability challenges of meat quality and authenticity emerged, and they are perceived ability to ascertain meat quality and perceived trust in meat certification and verification.

5.3.2.4.3.1 PERCEIVED ABILITY TO ASCERTAIN MEAT QUALITY

One participant stated that, using physical observations, it is possible to ascertain and verify meat quality of beef cattle arriving at the saleyard. In terms of ascertaining the qualities of cattle, the participant stated the following.

> *"Well, we look for the weight, the condition so the fat cover. You will see that sheep there are a score two sheep and uh, and, and it's. Yeah, we're trained. That one there's a score one, and then if you go up the road here, the fatter they get and there's threes and fours and fives" (Participant P11)*

5.3.2.4.3.2 PERCEIVED TRUST IN CERTIFICATION AND ACCREDITATION

The same participant also stated that information on the authenticity of information related to cattle could be verified using the accreditation certificate issued by a competent authority.

> *"Yes. So we'll only sell them that way if the vendor provides the certificate. So we will not take their word of mouth. They have to actually supply the certificate saying yes, I am accredited." (participant P11)*

The participant also added the following regarding the types of meat quality accreditation programs that are utilised by the farmers to ascertain the authenticity of the quality of beef cattle sold in the sale yard.

> *"It is the Greenhams accreditation program, the never ever accreditation program. The eligibility needs to be no grain, no antibiotics" (Participant P11)*

However, that same participant stated that while the NVD remains the primary means of verification, they assume that information presented by the farm are trustworthy

> *"All we have is that vendor declaration from the farmer. So we just have to trust their information, and by signing the declaration they sending, they are declaring that this information is true and correct." (Participant P11)*

The same participant also mentions the following.

> *"if it's not correct that comes back to them. We could do checks visibly but we don't know the past of an animal. We just have to take the vendor at their word." (Participant P11)*

5.3.2.4.4 ANIMAL WELFARE

Both participants did not perceive any traceability challenge with their ability to ascertain the welfare status of the cattle in the saleyard. In this area, one sub-category emerged namely perceived compliance and monitoring of animal welfare.

5.3.2.4.4.1 PERCEIVED COMPLIANCE AND MONITORING OF ANIMAL WELFARE

One participant mentioned that all the livestock that are transported to the saleyard are provided with water and comfortable pen condition during their stay in the saleyard.

> *"We don't feed them here because they've all had a feed before they come, but they have all got water. "So they were only here for not even a couple of hours. Well, so they will start. The sale will start at 10 probably finish today twenty past 10. As soon as the sale finishes, they will start going into trucks and going"(Participant P10).*

Another participant stated that the visual assessment conducted in the saleyard is used to ascertain the physical and mental welfare status of the cattle before the sale at auctions.

> *"So temperament, if they are highly strong or if they are what we considered to be Gossage and Buckets overflowing as such and they are very unhappy. Then we will send them where there's going to be minimal contact with humans"(Participant P10).*

5.3.2.5 FEEDBACK FROM CASE STUDY PARTICIPANTS AFTER THE SUPPLY CHAIN MAPPING STEP

As mentioned in Section 4.4, each participant was contacted after the supply chain mapping step was concluded to discuss and prioritise potential traceability challenges being faced in the chain. The aim was to obtain feedback from each participant concerning the perceived criticality of the traceability challenges faced and their willingness to progress to the next step (i.e. baseline data collection), Phase

2 (technology intervention), and Phase 3 (post-intervention).However, the feedback received from each participant indicated marked differences in perceived traceability challenges, level of criticality to their business, and willingness to explore areas of improvement in visibility and traceability. The farmer (Participant P08) was interested in exploring opportunities for monitoring animal behaviour and possibly to support early detection of oestrus in beef cattle. The participants at the saleyard (Participant P10&P11) did not proceed further in the study because they did not perceive any challenges with their traceability and did not perceive any risks to their current traceability to organisational operations. Based on the feedback received from supply chain participants, quantitative baseline data was obtained from the farmer (Participant P08) to assess the perceived level of visibility to potential traceability challenges related to animal welfare.The next section presents the key findings from the baseline data collection phase with the farmer.

5.3.3 STEP 3: PRE-INTERVENTION (BASELINE DATA COLLECTION WITH THE FARMER)

Quantitively baseline data was obtained from the farmer (participant P08) to assess the current visibility level and capacity for traceability of animal welfare in terms of *behavioural monitoring and oestrus detection in beef cattle*. Table 12 below shows the farmer's perceived level of visibility to traceability challenges of animal welfare in the farm node. In terms of accessibility, the farmer believed that he has access to between 50-75% of information on the welfare status of the cattle based on visual observation on site. In terms of accuracy, the participant also believes that the information generated from visual observation is satisfactory and, in some cases, could be incorrect for detecting the welfare/oestrus detection in cows. The farmer believes the visual information utilised to ascertain the activity levels of the cows can only be updated when on site. Using the assessment formulae adapted from the work of Caridi et al. (2014), the total internal visibility is calculated as 3, indicating high visibility level based on visibility evaluation criteria **(See section 3.6.3.1, Table 9)**.

Table 12: Farmer's perceived level of visibility to traceability challenges in animal welfare (Node visibility assessment for behaviour monitoring and heat detection)

Prioritised traceability challenge (Farm node)	Access to less than 50-75% of information on welfare	Accuracy of exchanged information is usually satisfactory and only incorrect in a few situations	I some cases the information is updated when I ask for it	Node visibility

	Accessibility	Accuracy	Freshness and currency	Visibility score
Animal Welfare	3	3	3	3

5.4 PHASE 2: TECHNOLOGY INTERVENTION WITH THE FARMER

Following the baseline data collection step, the research held a consultative meeting with the farmer to discuss technology options to enhance visibility and capacity for traceability of animal welfare in the farm. Based on the feedback from the consultation meeting, the research proposed and implemented a low-cost RFID/NFC based wireless cow-activity monitoring system called Ovi-Bovi® to enhance visibility and traceability of animal welfare that includes monitoring cow activity behaviour and oestrus detection .The Ovi-Bovi monitoring system is shown in Figure 12 below. As seen in the figure below, the cow activity monitoring system includes 2 individual collar-worn wireless activity tags embedded with near field communication chip, a Mikrotik router board for internet routing and connectivity, 1 wireless receiver with antenna range of between 2 to 5 km wireless range in license-free 433 MHz band; and a Telstra wireless modem. The sensors followed the mobile activation procedure outline in the equipment manual and this is shown in the appendices (Appendix H)

Figure 12: The Ovi-Bovi monitoring system deployed in the farm

The experiment was conducted for 21days between November and December 2018 with both pilot and full implementation in the same period. To explore the applicability of the sensors, two female English Hereford cattle were utilised. The procedure for installation was as follows: Each NFC/RFID enabled MEMS-based accelerometer collar tag was activated and carefully placed around the neck of the cattle. Then the sensors were allowed to calibrate itself internally and also to establish a baseline for regular animal activity within a window period of 72hrs. The sensors were programmed to capture 128 accelerometer measurements per minute. This rate allowed the capture of slight movements in the cattle with characteristic frequencies of up to 1,067 Hz. After calibration was achieved, the NFC collar tags sent activity data to a receiver where further processing was performed and uploaded to the internet dashboard through an internet gateway installed on the farm. The dashboard was web compatible with desktop, and mobile web platforms and the information was available to the farmer. The dashboard was accessed via the following secure link: utas.ovi-bovi.com?.

5.4.1 ANALYSIS OF FINDINGS

Figure 13 and Figure 14 below shows the activity chart for two cows monitored over a 21day period. It shows the activity profile for the cattle as line chart plot across three axes :(a) the y-axis showing activity metrics and this indicates the activity levels of the cattle with low activity/sedentary (-1) to very high cattle activity (+2); (b) the x-axis: indicating days during which the activity patterns were measured; and (c) the z-axis – rumination minutes per hour. Figure 13 shows the activity pattern for Cow No. 1. The trend lines are broken and missing a significant amount of signal between November 11th and 17th November 4$^{th.,}$ indicating non-activity. This non-activity was due to lost collar tags due to accidental removal from the neck of the cattle. It was not clear when the incident took place, but the best estimate was on the 11th of November after initial calibration. The researcher visited the farm along with the farm, and an active search began to locate the tag. The tags were later found on the 16th of November and were safely placed again on the cattle. However, the same incident occurred on the 17th of November. It was suggested by the farmer and in agreement with the researcher that the cattle may not be comfortable with the tag. As a result, the experiment was cancelled for one of the cows (Cow No 1).

Figure 14 below shows the activity chart for Cow No 2. The trend charts indicate significant capture of activity patterns. The breaks in the trend indicate sedentary behaviours which were accounted for as non-activity. The charts show two different colour profiles, light and dark. The white trend line indicates estimated ruminating behaviour per minute for the cattle. The calculation of this behaviour was based on the internal algorithm developed by Ovi-Bovi to show how the animals behaved in the farm. The chart below showed a consistent pattern in animal ruminating behaviour and slightly healthy activity on the farm. On the 4th of December, at 10 pm estimated ruminating behaviour was 9min/hour indicating the amount of time the animal was stationary for that period chewing the cud. The sensors also picked another ruminating behaviour at 11:48 pm that revealed 1min/hour, indicating that the animal may have been in very sedentary behaviour, almost sleeping. On average, the animal exhibited a regular activity pattern between 0.0-0.5, indicating a relatively standard pattern of walking, eating, and resting/chewing the cud. No extreme activity pattern was recorded in the intervention period.

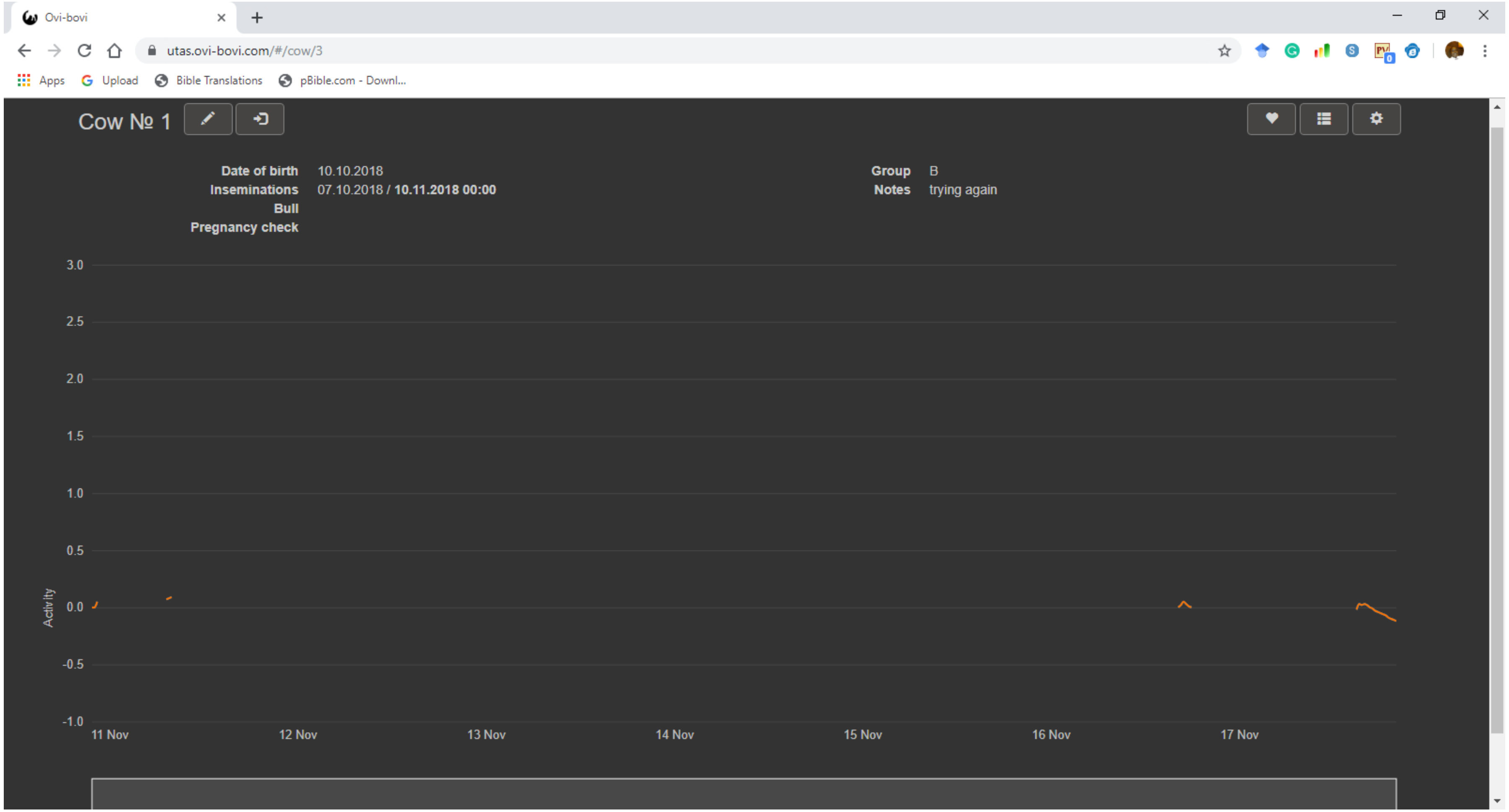


Figure 13: Activity profile for Cow No1 during the technology intervention (with the pilot) and showing limited activity

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Figure 14: Activity profile for Cow No. 2 during the technology intervention (with the pilot study

5.5 PHASE 3: POST-INTERVENTION EVALUATION

In the post-intervention phase, the research conducted a semi-structured interview with the farmer to understand the perceived role and potential impact of the technology intervention on organisational visibility and traceability of animal welfare in the farm. The analysis of the semi-structured generated to key themes and these are perceived impact of IT intervention on the traceability of animal welfare and perceived technology impact on information quality. The core categories include the impact on organisational behaviour, perceived commercial benefit, information quality criteria, internet connectivity. Each of these is presented in detail below.

5.5.1 PERCEIVED IMPACT OF IT ON TRACEABILITY OF ANIMAL WELFARE

The participant did not perceive any impact of the technology intervention on the traceability of animal welfare because of the ***limited scope of the business venture***.

> *"For me, No, but I think if I am. it's more of a, my farm is a bit of a hobby farm. But if I was actually running a full-blown cattle farm where that was my actual core business, I could totally see the benefit of it" (Participant P08).*

The participant also stated that state that the technology intervention did not impact ***organisational behaviour*** regarding the approach to welfare monitoring, including animal behavioural monitoring and oestrus detection.

> *"So if i know that they are getting up and down and they are feeding, and I can tell that by when I am there because they are putting on weight. When you are there, there are not all skiddish and they calm and relaxed, they are likely to be like that when I'm there next time so you know what I mean? So, um, I'm not sure how it would change my, yeah, my behaviour when it comes to the way I manage my farm". (Participant P08).*

The participant stated that the technology intervention did not provide any ***clear commercial benefit*** for oestrus detection and improve reproductive performance when compared to the performance of visual observation technique combined with the natural instinct of bulls.

> *"It is just when they are on heat we actually can tell, um, and the bulls, certainly know when she's on heat. So, um, and if that were in there for three months, as the bulls with the cows, so that three months we know you've got three cycles of the cow, the*

> *chances are pretty high and she'll be sorted out." (Participant P08)*

The farmer also stated that the technology intervention did not fit onto the *focus of the farm objectives* due to the ***relatively small size of business operations*** and *different value proposition*. He stated that the technology may be of value to larger cow farmers in the dairy industry that use artificial insemination for cow-calve operations

> *"For me now, if you are talking about animal welfare and, and you are talking about how tracking the cow and then cycles and stuff like that. Its a big part of what this program does. I can see it being a massive benefit for those that run AI farms. I don't see it being a massive benefit for those that do not. Okay. That is pretty much as simple" (Participant P08)*

5.5.2 PERCEIVED IMPACT ON IT INTERVENTION ON INFORMATION QUALITY

This theme describes how participant's perception regarding the impact of the technology intervention on information quality. The core category that emerged is to **usefulness**, and **currency and freshness**. In this context, the participant stated that he did not perceive the *usefulness of the data* generated by the sensors in terms of its useability for monitoring the activity status of the cows.

> *"Yeah. But then what do you do with that data anyway? Cause if you're not going up there?". (Participant P08)*

The participant perceived a negative impact of the technology intervention on information quality in the area *of freshness and currency*.

> *"It almost probably annoy me if it was sending me SMS every time they stood up. Do you know what I mean? Cause I've got a lot of work and if I'm getting a ping every time that they stood up it's like, yeah, I know. They sit up, they stand, they get up, they get down and get up. You know what I mean? So It's probably not a massive okay tool for me. It's certainly what I'm saying though is It's certainly an interesting thing, I just don't see it though for my self". (Participant P08)*

The farmer also mentioned the quality of information generated by the sensors ***lacked reliability*** because it is negatively impacted by **poor internet connectivity.**

> *Thus, Uh, yeah, a little bit. Cause I mean, everything's now uploaded live to a cloud or something. most apps now require*

> *some level of internet. And if you look at even this as an example sends an SMS and the rest of that the rest of it potentially. Having a good strong Internet connection's pretty quick to make sure that you got the data as soon as possible. Because If you're making decisions off the data, you want to make sure that the data is accurate and up to date and alive. And if you're only going to get I think only 50% accurate and you're doing an AI program, and that's also only 50% accurate and yeah-, you are shooting the breeze, you know what I mean? So yeah, you want to make sure that, yeah. I think having a strong internet. (Participant P08)*

5.6 SUMMARY OF SUPPLY CHAIN MAPPING, BASELINE DATA COLLECTION, TECHNOLOGY INTERVENTION AND POST-INTERVENTION FOR CASE STUDY 1

This section presents a summary of the findings from case study 1. The research explored traceability challenges impacting small businesses along the pre-slaughter segment of the red meat supply chain. A total of 3 participants were involved in this case study comprising of a farmer/road transport, and 2 saleyard administrators. At the level of operations, the priority of traceability was markedly different from both small businesses. In the farm/cattle transport, the key focus of traceability is on animal welfare, specifically with monitoring animal behaviour and well being. In the saleyard, all aspects of traceability are prioritised covering issues of provenance, meat safety, meat quality, and animal welfare. At the level of technologies, IT use and adoption amongst the small businesses were markedly different. The farmer preferred limited interaction with technologies on the farm. However, the saleyard deployed a number of technologies to support traceability and maintain transparency along the chain. At the level of information, the key data requirements are linked to NVD and accreditation information.

In providing feedback from the supply chain mapping exercise, the participants at the saleyard operations did not perceive any challenge with their traceability. The farmer did not perceive any challenge with existing traceability practices, particularly with regards to animal welfare. However, he was interested in exploring opportunities for improvement using new technologies of animal welfare. As a result, baseline data collection focused on the farmer. The baseline data collection showed that the farmer perceived his level of visibility to animal welfare monitoring to be high, with a score of 3. The farmer believed that there could be areas for more improvement in information quality and visibility to support enhanced monitoring of the welfare of the cows. In the technology intervention, the research deployed a wireless cow activity monitor to enhance the visibility of information and traceability of animal welfare on the farm. The key focus of animal welfare was related to animal behavioural monitoring and oestrus detection. The technology intervention showed the sensor technology could play a role in the traceability of animal welfare in the farm and also illustrates the feasibility of the utilisation of the sensors. Although there were some technical challenges that were beyond the control of the researcher. These challenges included poor internet connectivity, geographical terrain, animal temperament, and difficulty of tag and antenna connectivity influenced by changes in grazing location on the farm. These factors contributed to how the participant perceived the role and potential impact of the technology intervention of enhanced visibility and traceability. In the post-intervention evaluation, the farmer provided the following feedback as follows :

- The farmer did not perceive any significant impact of the technology intervention on traceability and visibility of information related to animal welfare.
- The participant believed that enhanced information quality, especially in terms of currency and freshness of information on animal behavioural status, could negatively impact organisational operations and potentially poses a technical nuisance to the business. In this context, the participant also felt that the technology intervention could impact negatively on business operations.

In evaluating the technology intervention, the participant believed that the business sector, business size, the value proposition of the technologies and cost-benefit performance are crucial criteria that impact perceived role, utilisation and successful adoption of the system in the farm. None of these criteria was believed to be met by the technology, and the participant held the belief that the technology intervention lacked usefulness to the business.

Chapter 6

Analysis of Findings: Case study 2

6.1 INTRODUCTION

This chapter presents the findings that emerged from the analysis of field data for case study 2, a preslaughter beef supply chain segment aligned to retail butcher 2 operating within the Tasmanian red meat industry. This chapter aims to explore traceability challenges faced by small businesses operating in the pre-slaughter segment of the beef chain and to understand the role and potential impact of deploying low-cost mobile technologies for responding to the critical challenges. The presentation is organised in 3 parts, and these are pre-intervention (supply chain mapping and baseline data collection), technology intervention and post-intervention and evaluation. Each section is structured using the three-phased strategy to provide answers to the research questions. The breakdown of the section of the analysis chapter is as follows. **Section 6.2** presents an overview of the key findings that emerged from case study 2. **Section 6.3** presents the analysis of key findings that emerged from **Phase 1-Pre-intervention** (supply chain mapping and baseline data collection). Section 6.4 presents the analysis of findings from **Phase 2-(technology intervention)**. The key findings from **Phase 1 and Phase 2** will provide answers to **Research Question 1**: *How can low-cost mobile technologies be utilised and deployed amongst small businesses in red meat supply chains to support traceability and for responding to challenges faced?* Section 6.5 presents the analysis of findings from **Phase 3-Post-intervention evaluation**. The key findings from **Phase 3** will provide answers to **research question 2**: (a)*What criteria do small businesses in red meat supply chains use in evaluating the role and potential impact of low-cost mobile technologies in supporting traceability and for responding to challenges faced*?; (b) and **research questions 3**: How *can a small business traceability framework be developed to support the implementation and evaluation of low-cost mobile technologies to support traceability and for responding to challenges faced?* **Section 6.6** summarises the findings from the chapter.

6.2 OVERVIEW OF KEY FINDINGS FROM CASE STUDY 2

This section presents an overview of key findings for Case study 2, a post-slaughter segment of a Tasmanian beef chain. As presented in Chapter 4 (see Section 4.3,

Figure 11), Case study 2 is linked to Case study 1 (i.e. farmer/road transport and saleyard operations) and both segments constitute a Tasmanian beef supply chain. A total of 3 small businesses were interviewed in this segment, and they include the stock agent, wholesaler, and retail butcher. The key participants include 1 stock agent (P12), 1 wholesaler (P14) and 1 retail butcher (P15). In step 2- supply chain mapping, 3 participants were interviewed. After the mapping exercise, each participant was contacted to discuss the traceability challenges faced in their organisational operations and to obtain feedback concerning their willingness to explore areas where low-cost mobile technologies can assist in responding to some of these challenges. This discussion is required for each participant to progress to step 3 (baseline data collection); phase 2 (technology intervention) and Phase 3 (Post-intervention). However, only the retail butcher agreed to progress further in the study. Thus, the analysis of findings in baseline data collection step (step 3); Phase 2 (technology intervention); and Phase 3 (post-intervention) focuses on the retail butcher. The next section below presents the analysis of findings from the supply chain mapping exercise for case study 2 starting with the stock agent and then followed by the wholesale and then retail butcher. The key findings that emerged from this case study are as follows:

1) **Phase 1 -Pre-intervention (Supply chain mapping step):** The most significant traceability challenges were related to issues of meat safety and meat provenance, and these challenges were linked to the retail butcher. The stock agent and the wholesaler did not perceive any significant challenges with their current traceability practices, and as a result were not interested in progressing further in the study. **Visibility assessment conducted with the retail butcher the heuristics framework showed that the butcher perceived a moderate level of visibility to traceability challenges of** meat provenance (proof of origin) and meat safety (cold chain monitoring).
2) **Phase 2 (Technology intervention):** 2 low-cost mobile technologies were deployed in the butcher store to enhance visibility and for responding to traceability challenges in areas of meat provenance (verification of meat origin) and meat safety (temperature monitoring). The intervention showed that low-cost mobile technologies could play new roles in traceability in responding to challenges related to meat provenance and meat safety.
3) **Phase 3 (Post-Intervention):** The retail butcher perceived new roles and potential impact of the mobile technology intervention on traceability in the

butcher store, particularly in areas of information quality, risk mitigation, enhancing organisational behaviour, and overall visibility of operations.

The next section below presents a detailed analysis of the key findings from Case study 2.

6.3 PRE-INTERVENTION (SUPPLY CHAIN MAPPING)

6.3.1 STOCK AGENT

Participant P12 is a livestock stock agent aligned to retail butcher 1. The stock agent act as a middle in facilitating the fulfilment of red meat orders (live cattle and lamb) on behalf of 8 butcher stores and a red meat wholesaler in Hobart, Tasmania. The supply chain map of organisational traceability practices for the stock agent is presented in Appendices (See Appendix I).

6.3.1.1 OPERATIONS

The stock agent conducts five main activities, and they include *order receiving and processing, sourcing of livestock and purchasing, payment and change of ownership, transport scheduling, and feedback.* In the order receiving phase, the stock processes new orders using two main approaches.in the first approach, the butcher placed new stock orders for red meat at the beginning of the week. The participant stated that most butchers are interested in purchasing high-quality meat product with specification around weight, body condition, fat, and dentition.

> *"For the butchers, i always get their order off the butcher each Monday and get the details of what they require. I know each butcher requires 18-20kg lambs, each butcher requires 22 to 24kg beef carcass.I'm talking of carcass weight now. And I always lookout for the best quality lambs in the sale yard and because I know they have got to pass it on to the consumer and they need the best quality available" (Participant P12)*

In the second approach, the butcher relies on the relationship built with local farmers in the state to inquire about stocks that are available for sale. Based on the feedback received from the farmer, the stock agent can contact each butcher to inform them of the range of red meat stocks that are available for purchase. This approach to sourcing is similar for both beef and lamb. Two primary market sources are utilised for fulfilling stock orders, and they include the saleyard auction complex at Powranna (in case study 1), and by purchasing live cattle directly from the farmer. Sourcing between saleyard and farmer directly depends on factors such as *day of* *sales, supply chain relationships, and market opportunity*. In the saleyard, the stock agent mentioned that long term interaction with farmers provides the opportunity to gain access stock availability and thus improves his chances of fulfilling client orders more quickly. However, if the farmers are unable to fulfil that amount of order requested, then the stock agent contacts other stock agents in the supply chain to inquire about stock availability for purchase.

> *"All the farmers I have been dealing with, I know the time of the year when they have cattle. If I cannot source them through a farmer, I go through [another] a livestock agent and ask if he has got agents and what sort of cattle they got about. To fulfil my orders yes (phone calls)." (Participant P12)*

The next phase is the assessment and selection of stocks. The stock agent mentioned three main assessment and selection criteria to determine the best cattle for purchase from the farm., and they include farm production practices, animal body condition and physical wellness, and dentition. The stock agent also utilises meat quality criteria such as age and, dentition as two critical indicators for selection of beef cattle stock for butchers.

> *"The age which should be at least about 9months or 12-16 months. Love to buy them, make sure I get the two teeth one or going on a little bit older but sometimes the 4 teeth are purchased for the butcher. I love to buy them, but make sure I get the two teeth one or going on a little bit older, but sometimes the 4 teeth are purchased for the butcher." (Participant P12)*

The third phase is the mechanism for price discovery. Depending on the marketplace, if the stock agent has purchased the cattle directly from the farmer, then a dead carcase weight pricing mechanism is utilised. This approach to pricing means that the farmers receive the equivalent value of the cattle after it has been slaughtered and accessed. Three important metrics utilised by the participant to ascertain the quality of the meat include ***fat content, meat colour, and dead weight.*** The second pricing mechanism is payment based on live weight at the saleyard. In this approach, the stock agent negotiates a price for the cattle based on visual and physical characteristics of the cattle at the farm and proposes a price. Here weight, body condition, temperament, and dentition are also considered essential metrics for evaluating the value and market price for cattle.

> *"For the farmer, I give them a dead weight carcass weight price. In the saleyard all of the cattle are weight live weight, and we work out a live weight price in the sale yard". (Participant 12).*

Once pricing is finalised with the farmer, the livestock is transported to the processor. One participant stated it is the responsibility of the butcher to transport the livestock either from the farm or through the saleyard down to the processor.

> *"When I buy the cattle from the farmer, he [the butcher] usually arranges his truck to the abattoir".(Participant P12)*

After processing, the stock agent stated that it is the butcher that organised for the transportation of the carcase to the store.

> *"I do not arrange that. The butcher arranges that themselves. They are in contact with abattoirs, and they work out Tasmanian trucks, his contact name is walker, he is carcass transport company, and he takes them all around the state".(Participant P12)*

6.3.1.2 TECHNOLOGIES

The stock agent utilises three main technologies to support organisational operations, and they include email, desktop computer and mobile phone. The email is used to send and receive information from other clients, as well as send the carcase feedback sheet to the farmer for pricing negotiation. The desktop computer is used to manage records and to connect with NLIS should there be a need for upload of NVD documents on behalf of clients. The mobile phone is used primarily for communication with clients (butchers), other stock agents, and farmers.

> *"Probably to arrange everything I mention it over the phone but to send the results of the kill of the carcass weight I use email then". (Participant P12)*

6.3.1.3 INFORMATION

The key the critical traceability information is captured through the NVD form such as the name of the farmer and address, breed of the cattle, veterinary history, age and the RFID tag number. The participant also receives feedback information from the processor after slaughtering, and this is used to ascertain pricing for cattle purchased directly from the farmer. The feedback information contains carcase yield indicators such as weight, fat colour, body condition score.

6.3.1.4 POTENTIAL TRACEABILITY CHALLENGES IN STOCK AGENT OPERATIONS

The interview in this section focused on understanding the potential traceability challenges impacting the stock agent operations and the current role of technologies. Four core categories of traceability challenges emerged, and they are related to *meat* *provenance, meat safety, meat quality, and animal welfare.* The key findings that emerged from these core categories are presented in the next section below.

6.3.1.4.1 MEAT PROVENANCE

The stock does not perceive any traceability challenge with regards to meat provenance. One sub-category emerged concerning potential challenges of meat provenance, namely **perceived compliance.**

6.3.1.4.1.1 PERCEIVED COMPLIANCE

He mentioned that ascertaining the provenance of cattle at different points in the supply chain is possible using the information from the RFID tag number and the NVD document.

> *"Yes, with all the cattle because all the cattle are ear-tagged now. It is with tracking, and that track is recorded in the abattoir as well so that when they kill, that carcass can be traced back from the butcher shop back to the paddock or the paddock back to the butcher shop, either way, it can be traced". (Participant P12)*

The same participant also stated the following.

> *"Usually with the traceability through the NVDs and the ear tags you can know more about the animal, the age which should be at least about 9months or 12-16 months". (Participant P12).*

6.3.1.4.2 MEAT QUALITY

The participant did not perceive any traceability challenge with ascertaining the information on the quality of each cattle purchased from the farm or through the saleyard. One sub-category concerning potential challenges of meat quality/authenticity, namely **perceived accessibility to meat quality information.**

6.3.1.4.2.1 PERCEIVED ACCESSIBILITY TO MEAT QUALITY INFORMATION

The participant believes that he has access to the kill sheet and with this information, it is possible to trace the quality performance to each carcase purchased.

> *"If I have got the cattle off the farmer the kill sheet comes back to me because I will like to check it to make sure the weights right, and also the fat score is right. Then I work out the price then pass it on to the farmer". (Participant P12).*

6.3.1.4.3 ANIMAL WELFARE AND MEAT SAFETY

The participant did not perceive any traceability challenge with animal welfare and meat safety. One sub-category emerged concerning potential challenges of animal welfare and meat safety, namely **verification of compliance.**

6.3.1.4.3.1 VERIFICATION OF COMPLIANCE

The participant stated that by visiting the farm, the environmental and welfare condition for each cattle can be ascertained to ensure that they have been raised in a safe and healthy environment prior to purchase.

> *"You have got to make sure that cow's clean, there is enough green, irrigated pasture or silage- So they do not cut dark. Nothing worse than getting it to a butcher shop and getting a dark cutting." (Participant P12)*

6.3.2 WHOLESALE

The wholesale business sells a range of meat products to local butchers and consumers. Meat products include beef, lambs, pork, goats, and chicken. *Participant P14* held the position of the operations manager in this enterprise and was interviewed in the business segment. The research mapped the organisational traceability practices across three levels, namely operational, technologies and information. The map of the organisational traceability practices can be found in the appendices (Appendix I). The next section presents the analysis of finding from the supply chain mapping exercise.

6.3.2.1 OPERATIONS

At the level of operations, the wholesale performs 4 major activities, and these are *order processing, procurement of cattle, scheduling for processing, and receiving of the carcase.* In the order processing phase, the local butchers (including butcher 1) send in new stock orders at the beginning of the business week, and this information is passed along to the stock agent or the participant purchases directly from the farmer aligned to the business.

> *"We buy it privately and through the sale yard".(Participant P14).*

If stock orders are purchased through the stock agent, the cattle are sourced from the sale yard. Regarding the stock agent, the participant, mentions the following:

> *"So we go to buy up north, and he knows lots of the farmers, what they have got about, and if they have not gone, we go to the sale yard vice versa."(Participant P14)*

Once the livestock has been purchased from farmer or sale yard, the participant arranges for a cattle transport to move the livestock to the meat processor in Devonport. At the meat processor, the cattle are slaughtered and chilled. The participant also arranges for a cold chain transport to move the carcase to the store in Hobart.

> *"Yes. Wxxxr transport. They do all the carton south out of Devonport, and it comes out of there it comes in mini trucks".(Participant P14).*

The same participant mentions the following

> *"Then I ring up abattoirs, tell them to put it on the truck, and they put them all in".(Participant P14).*

6.3.2.2 TECHNOLOGIES

The key technologies utilised include mobile telephone and temperature sensor. The mobile phone is used for communicating with suppliers and other clients, e.g. butchers. The portable digital temperature sensor is utilised for spot checks of carcases delivered to the store.

6.3.2.3 INFORMATION

At the level of information, the critical information being captured include carcase identification tags and feedback sheet. The carcase tag is an identification tag that follows the AUS-MEAT standard for identification of cattle. Important data element include type of red meat, e.g. beef, date and time of processing, address of processor, pen number, sex of cattle, and dentition. Each carcase tag is identified with a barcode label generated by the processor. The feedback sheet details the key quality performance indicators used by the stock agent and wholesale to assess the value of a carcase and the indicators include key data elements such as carcase weight, dentition, and fat score. A sample of the feedback sheet is shown in the appendices (Appendix J).

6.3.2.4 POTENTIAL TRACEABILITY CHALLENGES IN THE WHOLESALE OPERATIONS

The interview in this section focused on understanding potential traceability challenges impacting the wholesale operations and the current role of IT. Four core categories of traceability challenges emerged, and they are related to *meat provenance, meat safety, meat quality, and animal welfare.* The key findings that emerged from these core categories are presented in the next section.

6.3.2.4.1 MEAT PROVENANCE

The participant does not perceive any traceability challenge with provenance. Two sub-categories emerged concerning potential traceability challenges of meat provenance, and they are **perceived ability to verify compliance and perceived trust in stock agent verification and awareness of meat provenance**.

6.3.2.4.1.1 PERCEIVED ABILITY TO VERIFY COMPLIANCE

The participant believes that he can trace the origin for each carcase purchased back to the farm by contacting the stock agent or directly from the farmer.

> *"Well, we go through our saleyard. If it is coming on (from) private, it comes with a property name on it and so we know where it comes from, through the sale and so we can trace it through the saleyard. And so everyone records where it comes from through the saleyard".(Participant P14).*

6.3.2.4.1.2 PERCEIVED TRUST IN STOCK AGENT VERIFICATION AND AWARENESS OF MEAT PROVENANCE

Regarding the participants belief in traceability through the stock agent, the following was mentioned.

> *"Yeah. my agent knows them, and he rings them and he organizes all that. He gets them to the abattoir, he gets them killed, and they turn up here".(Participant P14).*

The participant also stated that apart from understanding the provenance of the meat through the stock agent, he is also aware that all of his cattle is solely Tasmanian grown. Regarding the ***geographical provenance*** of the cattle, the participant stated the following.

> *"All Tasmanian".(Participant P14)*

6.3.2.4.2 MEAT QUALITY

This participant did not perceive a traceability challenge with meat quality because each carcase delivered to the store is accompanied by the kill sheet. Two sub-categories emerged concerning potential traceability challenges of meat quality namely, **access to meat quality information and perceived lack of value towards MSA-based traceability**.

6.3.2.4.2.1 ACCESS TO MEAT QUALITY INFORMATION

This participant believed that the information on the kill sheet can be used to trace the quality performance for each cattle purchased through a farmer or from the saleyard using the sock agent

"No. We just get information about the weight, fat reading, male or female. Yeah, that is about it really".(Participant P14).

The participant also stated that in prioritising critical information on meat purchased, the most significant is price and not quality.

"No. Really all they need is more of price. We can try and bring good stuff in but which is going to buy it. Some do, some want better quality, some care but they are not concerned about whether it is grass-fed or grain-fed. Though all our meat is grass-fed. We try to keep reasonable stocks at reasonable price".(Participant P14).

6.3.2.4.2.2 LACK OF PERCEIVED VALUE OF MSA-BASED TRACEABILITY

In describing traceability of meat quality along the chain, the participant stated that he does not see the value of MSA.

"No. MSA graded is not worth the money pretty much".(Participant P14).

This lack of value proposition for MSA is based on the participant's belief that MSA does not provide sufficient transparency in information for consumers regarding the quality and authenticity of the meat purchased.

"With MSA, you know we have MSA 3,4 and 5- you see supermarket say MSA beef, that could be a cow and could be anything. They come under yearling-A or steer, but they just say MSA. So nobody knows what it means, what grade it is, they just say MSA and people think its good stuff, but if it falls into that category (i.e. 3,4 or 5), it could be anything. "(Participant P14)

6.3.2.4.3 MEAT SAFETY

The participant does not perceive any traceability challenges with ascertaining the safety of the cattle purchased in the supply chain. Two sub-categories emerged in relation to the lack of perceived potential traceability challenges in the area of meat safety, and these are **low risk perception to meat safety crisis and access to meat temperature information**.

6.3.2.4.3.1 LOW RISKS PERCEPTION TO MEAT SAFETY CRISIS

The participant mentioned that cases of condemned or significantly damaged carcase purchased through the saleyard are not uncommon.

"Yeah. So one got cancer of the bone, and then we throw them out and we'll get rid of them".(Participant P14).

6.3.2.4.3.2 ACCESS TO MEAT TEMPERATURE INFORMATION

Along the cold logistics chain, the participant stated that temperature information is captured using portable sensors to ascertain the safety condition of the meat before they are loaded into the cold store.

> *"We check the temperature as it comes in, and when the truck goes out in the morning or afternoon, we do spot checks". (Participant P14).*

6.3.2.4.4 ANIMAL WELFARE

The participant does not perceive any traceability challenge with ascertaining hr welfare status of the cattle along the chain because. One sub-category emerged concerning the potential traceability challenges related to animal welfare, namely, **compliance.**

6.3.2.4.4.1 COMPLIANCE

The participant believes that regulatory agencies conduct inspections in the farm, transport and saleyard, and this provides assurance to the buyers that suppliers are meeting mandatory requirements for safe handling and care of animal along the supply chain.

> *"RSPCA does foot checks on how they load the cattle, and also in the abattoirs how they handle to cattle, to make sure they do sort of things. They do all the checks, so we do not get too many problems with them".(Participant P14).*

The participant also added the following statement

> *"The RSPCA is pretty hard on them, so they check them out pretty regularly".(Participant P14).*

6.3.3 RETAIL BUTCHER

One participant in the retail phase of the post-slaughter segment of the red meat supply chain was interviewed. The retail butcher (*participant P15*) is the owner-manager of the butcher shop and has been operating the business for the past 15years. The retail butcher shop sells fresh meat products and offers a range of condiments to compliment the meat products. The fresh meat products include beef, fresh lamb, pork, frozen goat, chicken, quail, turkey, ducks, and wallaby. Beef, lamb and chicken are considered the top three sellers for the retail shop. The research mapped organisational traceability practice of the butcher shop across three levels: operations, technologies and information. The map of organisational traceability practices for the retail butcher is shown in the appendices (Appendix I).The detailed analysis of map is presented below in three levels of operations, technologies and information.

6.3.3.1 OPERATIONS

The butcher shop performs five main activities, and these include ordering, receiving of shipment, storage, breakdown/dis-aggregation, product display, and retail sales. In the ordering phase, the butcher order his stock wither from the private meat brand or through the sale yard. The boxed meat products are branded meat cuts that are owned by a major meat processor in Australia with a slaughterhouse in Tasmania.

> *"So we speak with our stock agent at JBS, Longford and they tell me what stocks are available. Because JBS is a large company, they draw from Victoria and all over Australia. They are getting from Queensland, and they are getting from New south wales. But the stock agent we speak to [for cartons] is up in Legana". (Participant P15)*

The orders made through the saleyard are processed through a stock agent. The importance of the stock agent in meeting supply and demand is attributed to the belief that they have: (a) better accessibility to information in the supply chain regarding locally grown stock for carcase and boxed meat stocks from farmers for over the hook transaction as well as at the saleyard; (b) relatively strong relationship with other fellow stock agents and as such are more knowledgeable of pricing throughout the production season; (c) and more experienced in evaluating quality of livestock stocks in the farm or at the saleyard prior to purchase. The butcher summarises the importance of the stock agent as follows:

> *"Oh, Yes, that why we have got Malcolm. He knows what he is doing. If I went out there I wouldn't know what I want. We buy it from the saleyard, and it goes through them, they process it, and they send it to us". (Participant P15)*

Once stock orders have been processed, they are delivered to a meat processing in Devonport who performs service kills on behalf of the butcher. Then the participant arranges with a cold chain transport to deliver the carcase to the store. The butcher mentions that only one cold chain operator transports hanging carcase from the meat processor to the retail and the company has been working with his businesses for more than 5years. Once the carcase is delivered to the store, they are stored in cold room to allow for further chilling before dis-aggregation and display on the cabinet. In the display and sales phase, the dis-aggregated meat products are placed in meat containers and displayed in the cabinet for the consumers to view and place their meat orders.

6.3.3.2 TECHNOLOGIES

The butcher operations utilise some IT tools, and these include one portable temperature sensors probe for spot checks, one Samsung ® mobile phone, an email account, and payment system for processing cashless payment. The role of the mobile phone is to facilitate communication with other supply chain actors, provide feedback about meat quality, and support scheduling and pickup arrangement with transport operators. The temperature sensor allows for spot check to ascertain the internal chilling condition of the cattle on arrival at the store. The email account is used to receive additional information from the processor, such as a summary of producer report sheet, i.e. kill sheet, receipt of payments from sale yard. Amongst the technologies identified, the butcher mentioned that emails are the least utilised in the day to day operations.

> *"They email it to my wife. I don't check the emails. I rely on the information in the store". (Participant P15)*

6.3.3.3 INFORMATION

At the information layer, four significant types of information capture components were identified, and they include the *kill sheet, receipts and invoices, temperature reading from refrigerating equipment, carcass/boxed meat label, and barcode label generated from cashless machine*. The butcher receives a copy of the kills sheet from the meat processor for the carcase purchase through the sale yard. The kills sheet presents a summary of the performance of the cattle and allows the stock agent and butcher to agree on an appropriate price with the farmer. It includes data elements such as cattle weight, fat content, date of slaughter, and body number. The second critical information received is the carcase tag. The hanging carcase are labelled according to AUS-MEAT standard with minimal data elements that include a barcode number, carcase weight, pen number at the saleyard, name of the processor, date of slaughter., location and address, age of animal, animal sex, kill date, pen number where the animal was bought (if in the saleyard), grade (e.g. MSA graded), dentition, and barcode number.

> *"They just tag them up for us. So I just know, as they tag them up for me. It contains information from the pen that the cattle*

came from, a fat grade of 3, sex is not applicable, weight". (Participant P15)

Upon dis-aggregation, the meat products are displayed on the refrigerating cabinet and a generic product tag is affixed to the eat tray in which the product has been placed. A sample of the display label is shown in Appendices (Appendix K). It shows the generic label used for the red meat product.

6.3.3.4 POTENTIAL TRACEABILITY CHALLENGES IN THE RETAIL BUTCHER OPERATIONS

The interview in this section focused on understanding potential traceability challenges impacting the retail butcher operations and the current role of IT. The core categories relate to issues of meat provenance to meat *provenance, meat safety, meat quality, and animal welfare*. The key findings that emerged from these core categories are presented in the next section.

6.3.3.4.1 MEAT PROVENANCE

Two sub-categories emerged from participant's perceived potential traceability challenges related to meat provenance along the red meat supply chain, namely **perceived challenge with ascertaining geographical origin, and product misidentification and substitution.**

6.3.3.4.1.1 PERCEIVED CHALLENGES WITH ASCERTAINING MEAT GEOGRAPHICAL ORIGIN

The participant perceives a traceability challenge with his inability to ascertaining the geographical origin of the provenance of the beef products. This inability is stated as limiting the marketing opportunity of beef sold to consumers due to limited access to information in the supply chain.

"I do not market my [beef] meat as Tasmanian like that. I market my chicken because I buy my chicken from Nichols. I buy my pork from the Scottsdale market. I market those as such. But our beef if the customer asks.I will give them a fair and honest answer. I can know where my products are coming from, but generally probably 90% of the time its Tasmania but not 100% of the time".(Participant P15)

The participant also stated that the depth of traceability information for beef is limited to the saleyard.

"I only know I buy the beef from the sale yard".(Participant P15).

Although the participant believes he could gain access to the information regarding full provenance for the beef, yet he does not consider it valuable for his business.

> *"I could find out the farm if I wanted to, but I don't" It's not something I need to know like that information will come to us but it's not something I have in my fingertips without looking it up". (Participant P15).*

However, with regards to the provenance of the lamb, the participant was able to confirm the geographical origin where they were purchased but not the location of the farm where they are grown.

> *"Yeah, I do not know the farm. I know that the [stock agent] buys many of our lambs from fern hill".(Participant P15).*

6.3.3.4.1.2 PRODUCT MISIDENTIFICATION AND SUBSTITUTION

The participant perceived traceability challenges with the meat processor due to instances of carcase misidentification and ***substitution*** both beef and lamb products.

> *"Occasionally something will happen to the abattoir, and you might get the wrong pen, they might mix things up. Someone might order side lambs, and he might end up with another's side lambs. It does happen occasionally. It does. Probably because we are only going to a small amount". (Participant P15)*

6.3.3.4.2 MEAT QUALITY

Two sub-categories emerged from participant's perceived potential traceability challenges related to meat quality along the red meat supply chain, namely **perceived access to MSA based verification, and perceived lack of transparency.**

6.3.3.4.2.1 ACCESS TO MSA-BASED VERIFICATION

The participant does not perceive any traceability challenge with ascertaining the quality of beef products because the products purchased from the meat processor are traceable through the MSA program.

> *"We buy our beef graded so like when you buy your beef, you are buying a yearling product so you are trying to buy an MSA graded product which can, like with the MSA that's guarantee tender beef. So that is, that is a registered trademark. We do not sell MSA on our tickets. We are not signed up with MSA, so I know not to market it as such. I cannot market it like that. I can still buy that".(Participant P15)*

6.3.3.4.2.2 PERCEIVED LACK OF TRANSPARENCY

The participant also raised issues with the lack of transparency of information on the quality of the live cattle purchased at the saleyard. However, the participant perceived a challenge with the transparency of information used to properly evaluate the quality of cattle at the saleyard before purchase.

> *"Yeah, it happens that the meat is not what we expect and we have to downgrade that and means we might have to use it for mince or sausages. If it is like . its got a bruise or something, you might as well cut that out and get rid of that. It does not always come up to certain expectations. It will not always come up to expectations. Generally, it does, but it does not always".(Participant P15)*

6.3.3.4.3 MEAT SAFETY

One sub-category emerged regarding participant's perceived traceability challenges related to meat safety, namely **perceived lack of visibility to meat temperature information**

6.3.3.4.3.1 PERCEIVED LACK OF VISIBILITY TO TEMPERATURE INFORMATION

The participant perceived a traceability challenge with the lack of visibility to meat temperature information in the cold store.

> *"I cannot monitor it. I am here though six days a week. Its only on hot days where the doors are getting opened and close all the time and things like that the temperature will always go up. Sometimes it is getting to 5,6,7 degrees, but the meat will still be in 5 degrees on there because the meat does not go up because of the high temperature it does not go up, but you just got to watch it and if it starts getting out at six, seven degrees. Then you go to turn, turn it off and go and get a new fridge. Its only happened twice last year". (Participant P15)*

The participant also believes this inability is linked to poor sensor performance of the refrigerating equipment.

> *"Like this fridge over here, we are having problems with. It was not defrosting properly. So it running up high out by five degrees on the analogue but It was still under, and it was not coming down on the temperature. You get a hot day. The doors are opening and closing so we keep an eye on that fridge on hot days. Occasionally we have to turn it off and defrost it because it does not get through defrost cycle" (Participant P15)*

6.3.3.4.4 ANIMAL WELFARE

One sub-category emerged concerning the participant's perceived traceability challenges of animal welfare along the red meat supply chain, namely ***supply chain trust.***

6.3.3.4.4.1 SUPPLY CHAIN TRUST

The participant does not perceive a traceability challenge with ascertaining that's animals have been appropriately cared for along the supply chain and before slaughter. The participant believes the issue of animal welfare is the primary responsibility of the meat processor and the farmer, and as such, does not relate to his business.

> *"It is in their best interests to care and do things right. The same as for us it is in our best interests to do things right. Otherwise, we are going to downgrade our products. You do not get a fat premium if you are not going to do things right" (Participant P15)*

6.3.3.5 FEEDBACK FROM CASE STUDY PARTICIPANTS AFTER SUPPLY CHAIN MAPPING STEP

As mentioned in Section 6.2, each participant was contacted after the supply chain mapping step was concluded to discuss and prioritise potential traceability challenges being faced in the chain. The aim was to obtain feedback from each participant concerning the perceived criticality of the traceability challenges faced and their willingness to progress to the next step (i.e. baseline data collection), Phase 2 (technology intervention), and Phase 3 (post-intervention). However, the feedback received from each participant indicated marked differences in perceived traceability challenges, level of criticality to their business, and willingness to explore areas of improvement in visibility and traceability. The stock agent (*Participant P12*) and wholesale (*Participant P14*) did not perceive any challenge with their traceability practices, and as a result, were unwilling to progress further in the study. The retail butcher (*Participant P15*) perceived some traceability challenges with meat provenance (proof of origin) and meat safety (temperature monitoring in refrigerating equipment) and was interested in experimenting with some technologies to improve visibility in both areas. Based on the feedback received from supply chain participants, baseline data collection was obtained from the butcher to quantify the level of visibility to the traceability challenges faced. The next section presents the analysis of key findings from the baseline data collection phase with the retail butcher.

6.3.4 STEP 3: BASELINE DATA COLLECTION FROM THE RETAIL BUTCHER

Table 13 and Table 14 below shows the butcher's perceived level of visibility to traceability challenges in areas of meat safety and meat provenance. The assessment conducted for meat provenance (meat origin) and meat safety (temperature information) respectively. In Table 13, the butcher's perceived level of visibility to temperature information in the store is presented. It shows that in terms of accessibility, the butcher believes that he has access to between 50-75% information on meat safety, i.e. temperature condition for the fridges. This assessment score is based on the premise that the amount of information generated by the digital sensors installed on the fridges in the store. In terms of accuracy, the butcher believes that the accuracy of the information generated by the sensors is usually satisfactory, and instances, where the information is incorrect, are not uncommon. In terms of freshness and currency, the butcher believes he can only be updated on the temperature condition of the fridge when he checks the sensors for the current temperature status. Based on the butcher's subjective assessment of the level of visibility to meat safety, the total internal visibility score obtained is 2.62, indicating a high visibility level **(See section 3.6.3.1, Table 10).**

Table 13: Butcher's perceived level of visibility to traceability challenges (Node visibility assessment to temperature information in the butcher store-meat safety)

Prioritised traceability challenge (Butcher node)	**I have access to a fairly good amount (50-75%) of the information**	**The accuracy of exchanged information is usually satisfactory, but situations in which the information is incorrect are not uncommon**	**In some cases, the information is updated when I ask for it**	**Node visibility**
	Accessibility	Accuracy	Freshness and currency	Visibility score
Meat safety	3	2	3	2.62

Table 14 below shows the butcher's visibility assessment concerning meat origin. In terms of accessibility, the butcher believes that he has between 50-75% information about the origin of the meat. This assessment follows the is based on the premise that the information currently available in the meat labels and carcase tags is sufficient to ascertain the provenance of the carcase. In terms of the accuracy, the butcher believes that accuracy of information exchanged by the stock agent is always satisfactory. In terms of currency and freshness of information, the butcher believes that information concerning meat provenance can only be updated after he asks the stock agent. Based on this subjective assessment, the total visibility score for the retail butcher is 2.88, indicating a high level of visibility to meat provenance **(See section 3.6.3.1, Table 10).**

Table 14: Butcher's perceived level of visibility to traceability challenges of meat provenance

Prioritised traceability challenge (stock agent node)	**I have access to a fairly good amount (50-75%) of the information**	**The accuracy of exchanged information is always satisfactory**	**Information is updated only when the node is asked to provide data**	**Node visibility**
	Accessibility	Accuracy	Freshness and currency	Visibility score
Provenance	3	4	2	2.88

6.4 PHASE 2: TECHNOLOGY INTERVENTION

Following the baseline data collection step, the research held a consultative meeting with the retail to discuss technology options to enhance visibility and capacity for traceability in areas of meat safety and meat provenance. Two low-cost mobile technologies were proposed, and these are: (a) meat safety intervention- a wireless temperature sensor monitoring system with mobile app integration; and (b) meat provenance intervention- an integrated meat verification system that comprises of QR code verification on mobile web and native mobile application.The butcher agreed to the proposal. The discussion of each the interventions is presented in the next section below.

6.4.1 WIRELESS TEMPERATURE SENSOR NETWORK INTERVENTION

The first intervention involved the implementation of SensorPush® Bluetooth®/Wi-Fi temperature sensor network in the butcher store. The sensor network allows the participant to remotely monitor temperature conditions in three refrigerating equipment within the butcher from anywhere with access to internet using the SensorPush® app. This implementation attempts to respond to critical issues of information quality in the area of *accuracy, accessibility and freshness and currency*. The implementation of the system in the butcher store is shown in the appendices (Appendix L). The system consists of three wireless SensorPush® Bluetooth sensors, a SensorPush ® internet gateway ,power supply and an internet connection. The router/internet gateway is linked to a cloud account where temperature can be accessed remotely through a SensorPush® mobile phone application from using 4G internet access. Data transmission for the temperature sensors was programmed to upload to the cloud every 1 minute, and this is continuously refreshed on the mobile phone simultaneously. The temperature data generated by the sensors is stored on a registered SensorPush® cloud account registered to the butcher. The sensors were also programmed to alert the butcher when chilling conditions in the three fridges exceed the maximum limit of 5°C. This technology took place between April-August 2018 in the butcher store premises. The pilot and final implementation were conducted at different periods for each equipment monitored. In the display cabinets, the pilot was conducted between March 4th -April 4th, 2018, while the final implementation ran between April 4th -August 4th,2018. In the cold room, the pilot was conducted between March 11th-April 11th,2018, while the full implementation ran between April 11th-July 21st,2018. In the front fridge, the pilot was conducted March 5th-April 5th,2018, while the final implementation ran between April 5th-July 29th,2018.

6.4.2 CONSUMER MEAT VERIFICATION SYSTEM

The second technology intervention involved the development and implementation of a consumer meat verification app. The development of mobile application followed the methodological approach described in Chapter 4 (See section 3.3.5.1). The user interface prototype of the mobile system is shown in Figure 15 below. It shows two different views of functionality designed, and they include namely; (a) NFC-QR code verification app for consumers; and (b) a data capture (backend) and data presentation (front end) to view traceability information for the registered meat product being traced in the supply chain. The backend is divided into two data capture sections, namely meat provenance and meat quality. The meat provenance section is capable of capturing key data elements related to the origin, location and history of the meat product as far back as the farm (if known by the butcher). The data element utilised in this intervention includes *the type of meat, brand, barcode identification number, geographical origin*, and *list of actors* involved in the movement of the meat product from farm to retail and *estimated dates and time stamps*. The meat quality section is capable of capturing key data elements of interest to the butcher and added value to consumers. Two key data elements were captured include breed, carcass weight, free-range, and feed input. The technology intervention for the consumer meat verification app followed the implementation protocol outlined in Chapter 4 (see section 3.4.2). In line with the protocol, the intervention was performed in two stages: pilot and final implementation.

In the pilot study, the butcher suggested that an experiment be conducted with lamb to explore the full potential of the ap since information o the full traceability can be ascertained. The researcher consented, and the pilot study focused on traceability of the lamb products. The lamb meat was boxed meat purchased from a local processor in the state. The pilot experiment was conducted for the lamb supply chain between October 1st – November 1st, 2018.

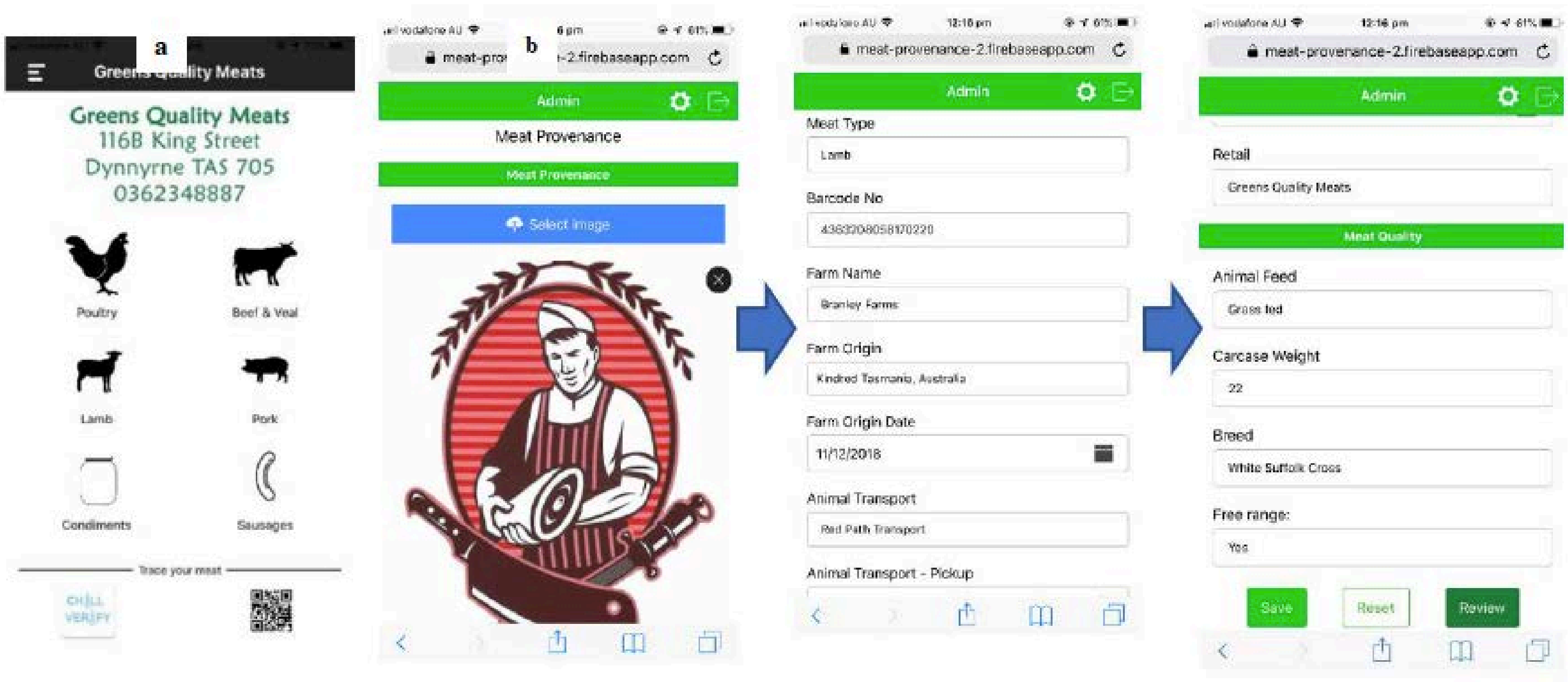

Figure 15: User interface for the native consumer app - user from the end (a), and (b) integrated back for the meat verification system (application for lamb)

Figure 16 shows the pilot implementation of the traceability system for lamb meat. It shows the traceability timeline for the lamb meat and the information that was captured from the product label. Additional information was also obtained through the butcher after contacting the meat processor. In the meat provenance section, the key data element captured includes the meat type, barcode number, farm origin, date of pickup, farm geographical origin, name of meat processor, cold transport, and retail butcher. In the meat quality section, the data element captured includes animal feed, carcase weight, breed, and animal farming approach. In the final implementation, the experiment focused on the traceability of a beef carcase. It shows the data elements captured for the retail butcher to demonstrate the applicability of the app for meat provenance. A branded boxed meat was purchased to demonstrate the applicability of the app. The experiment could not be conducted with the whole carcase purchased through the sale yard because the agreed date of intervention did not fall in the period of a livestock auction. However, the boxed meat provided an opportunity for the butcher to explore the applicability of the app for verification of meat origin to a specific supply chain node.

Figure 17 below shows the implementation of the mobile app for beef provenance. The key information on the provenance of the beef product was obtained from the stock agent. In the meat provenance section, the data elements captured include *the meat type (porterhouse), barcode number, farm geographical origin, name of the processor, name of cold transport, and reta*il. In the meat quality section, the important key data elements captured include feed input, MSA graded, Farm Assurance scheme (owned by the meat processor), animal husbandry approach, and age of the beef cattle. The implementation of the intervention for the provenance of beef took place between November 1st-December1st,2018.

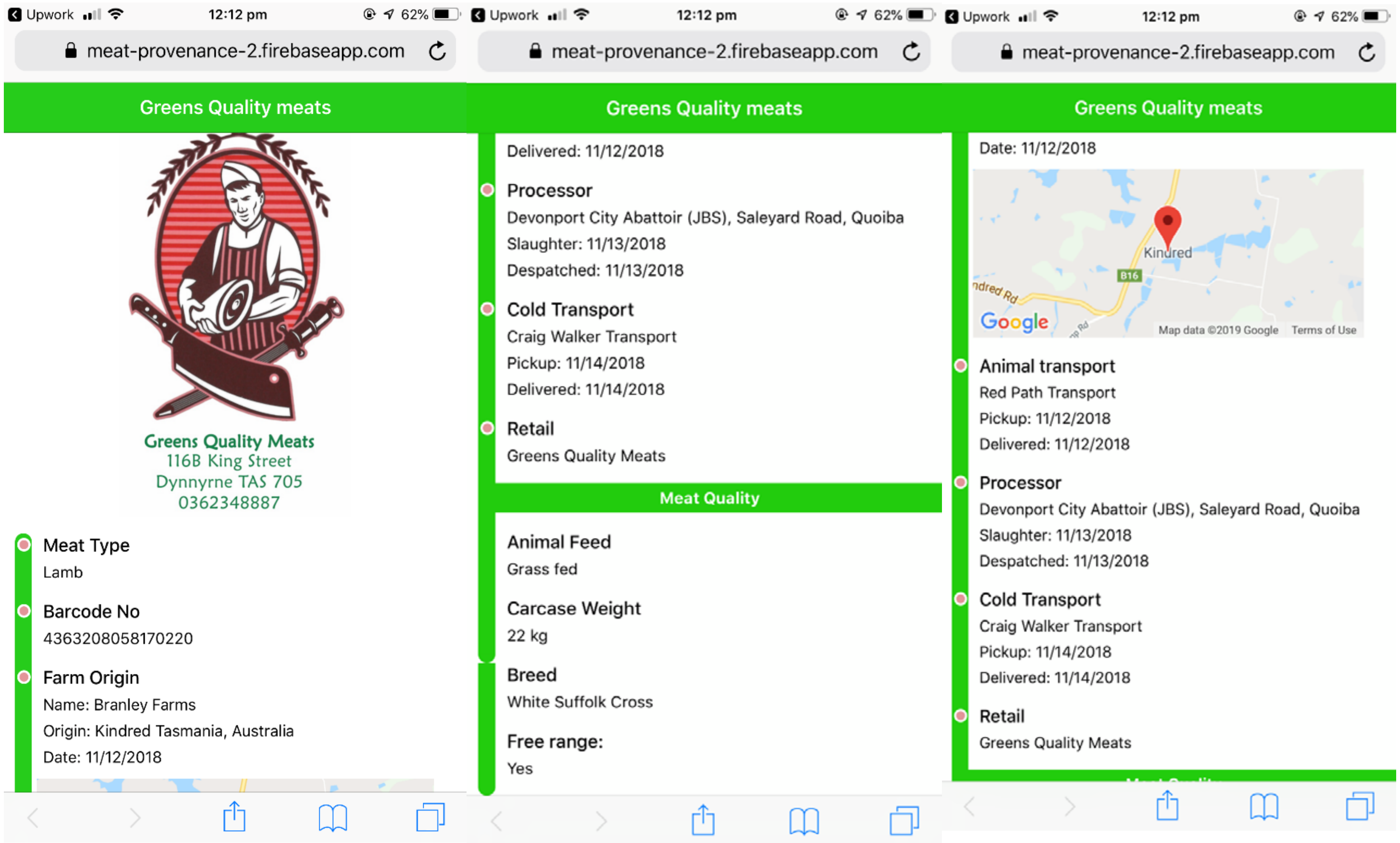

Figure 16: The pilot implement for the provenance of lamb meat

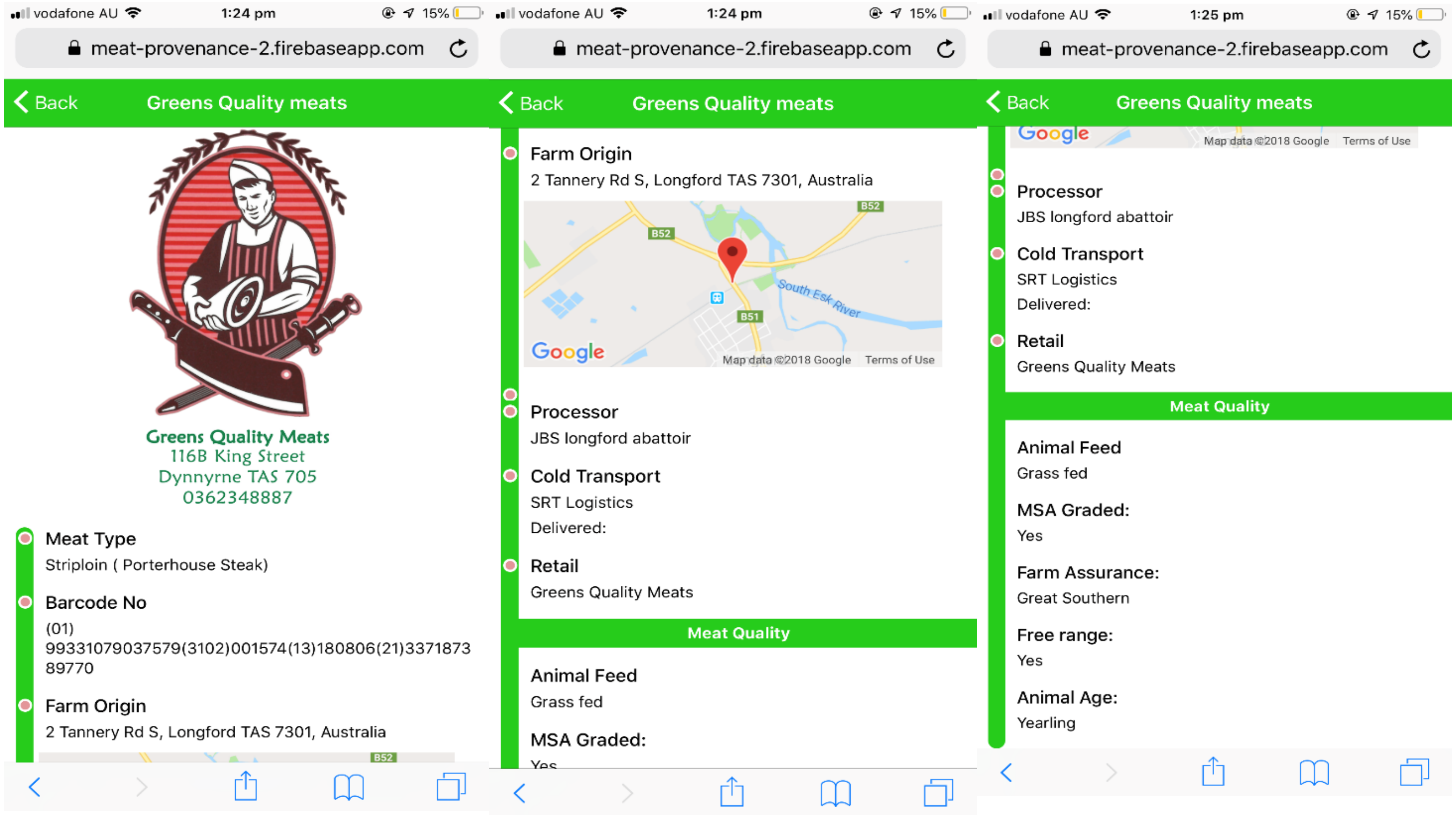

Figure 17: Mobile web application intervention for beef provenance

6.4.3 ANALYSIS OF FINDINGS

This section presents the analysis of findings from the two technology intervention implemented in the retail butcher store.

6.4.3.1 TEMPERATURE MONITORING

The key findings that emerged from the enhanced visibility in temperature information by deploying low-cost wireless sensors in the retail butcher store are shown in the figures below. Firstly, in Figure 18 below the temperature profile for the front display cabinet equipment is shown. It can be seen that the cabinet experienced an average temperature condition of 2.9^{o}C during the intervention period. It also revealed a minimum temperature of -2.2^{o}C and maximum temperature during the period is 24.4^{o}C. The maximum temperature was recorded on the day that the sensors were installed and are not be considered an accurate measurement for the display cabinet in that date and time. However, the sensors recorded 22 spikes that exceeded the threshold set at 5^{o}C during the intervention period. The butcher attributed these spikes to defrosting period, frequent opening and closing of the display cabinet during working hours, and the period when the cabinets were switched off during out of office hours.

The temperature chart for the cold room situated outside of the retail butcher store is shown in

Figure 19 below. The average temperature condition in the display cabinet is observed to be 4.5^{o}C. The minimum temperature of the cold room was 2.7oC while the maximum temperature of 30^{o}C was observed in the intervention period. The maximum temperature is recorded on the day that the sensors were installed and so were not considered accurate for that day. However, as observed from the chart below, the cold room experienced at least 25 temperature spikes above the maximum limit of 5^{o}C during the intervention period. The butcher attributed these spikes to defrost cycles of the cold room. Despite the spikes, the average temperature condition remained at or within the 5^{o}C threshold throughout the intervention period.

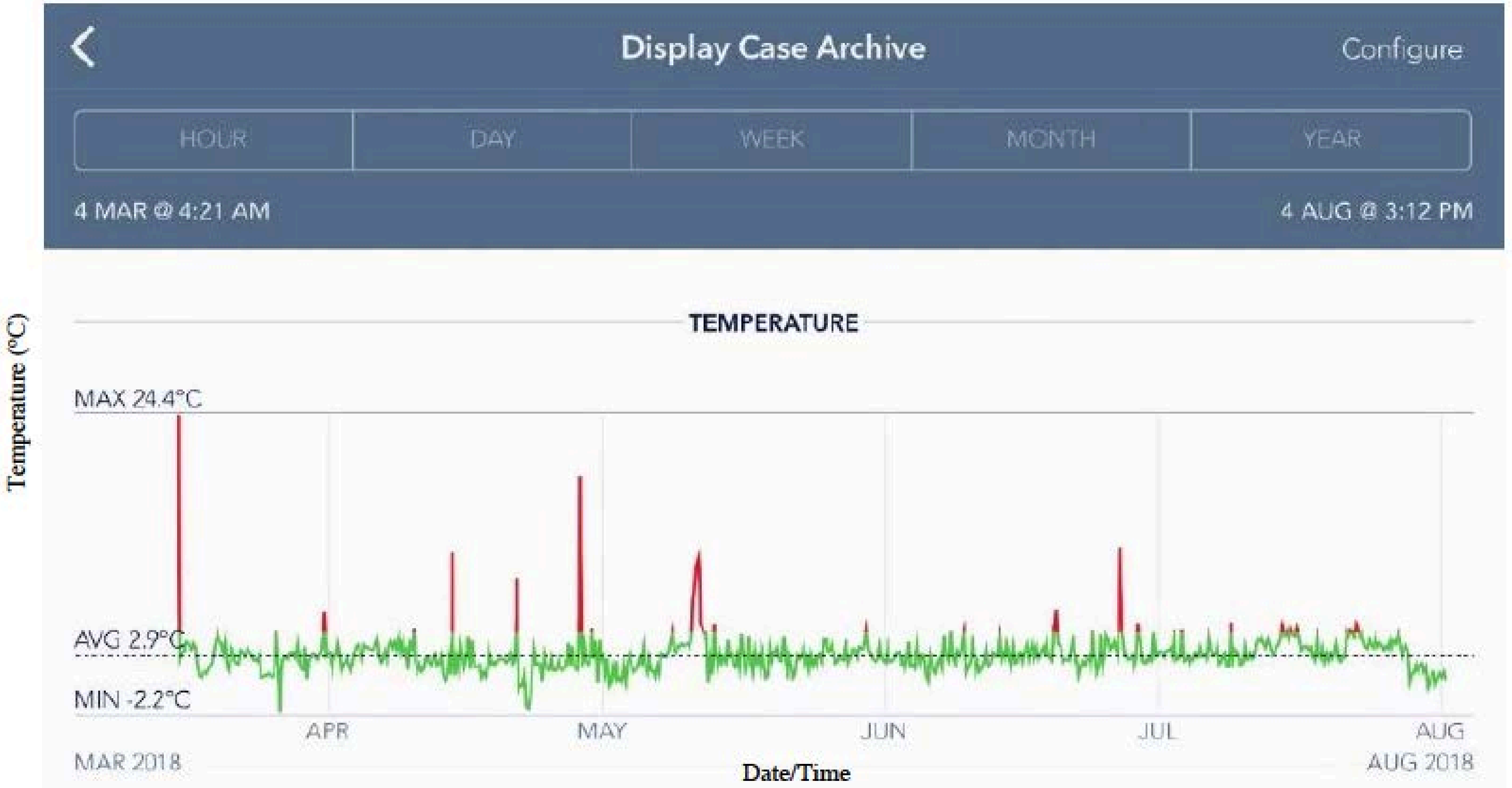

Figure 18: Temperature profile for a display cabinet in the butcher store

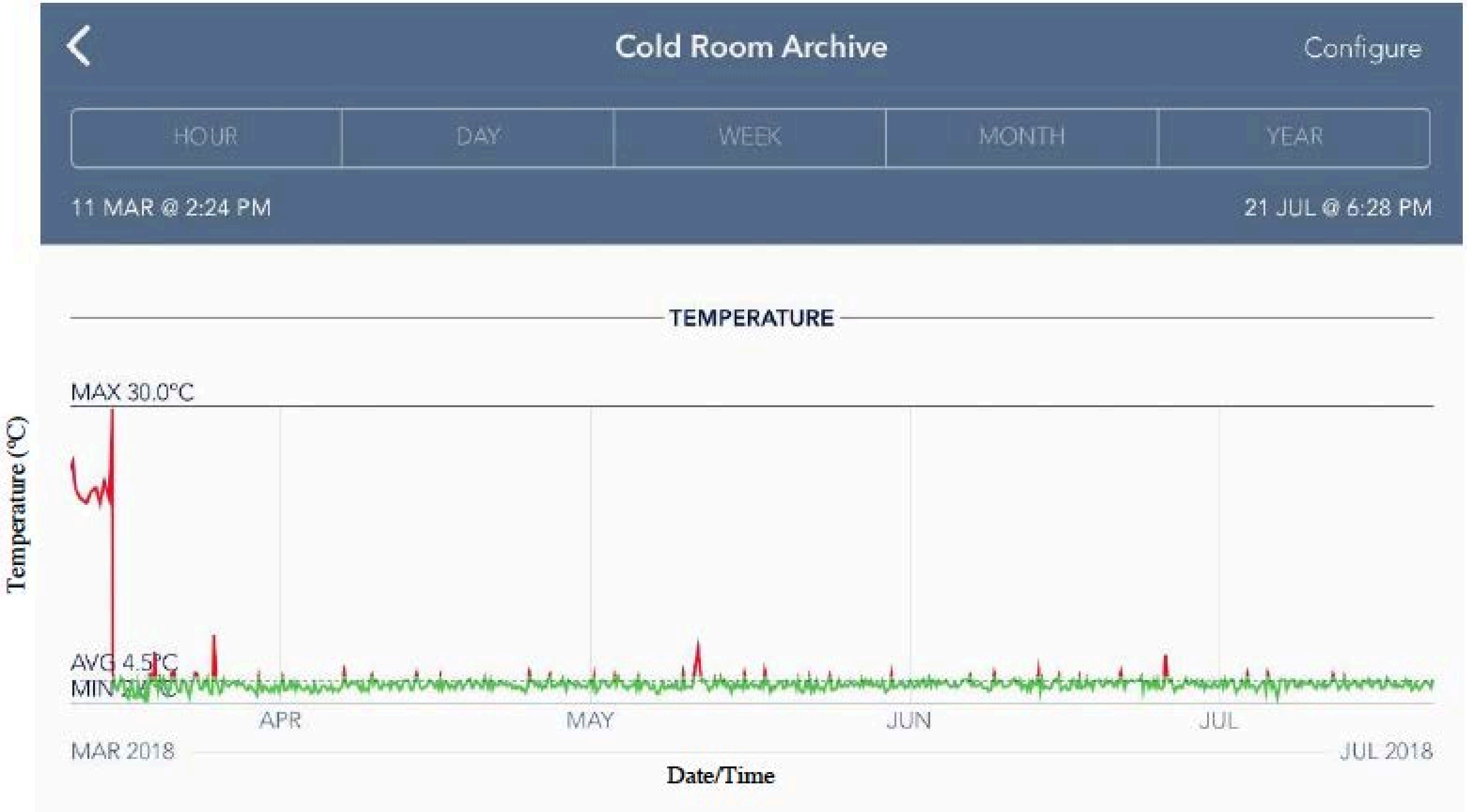

Figure 19: Temperature profile for the cold room in the butcher store

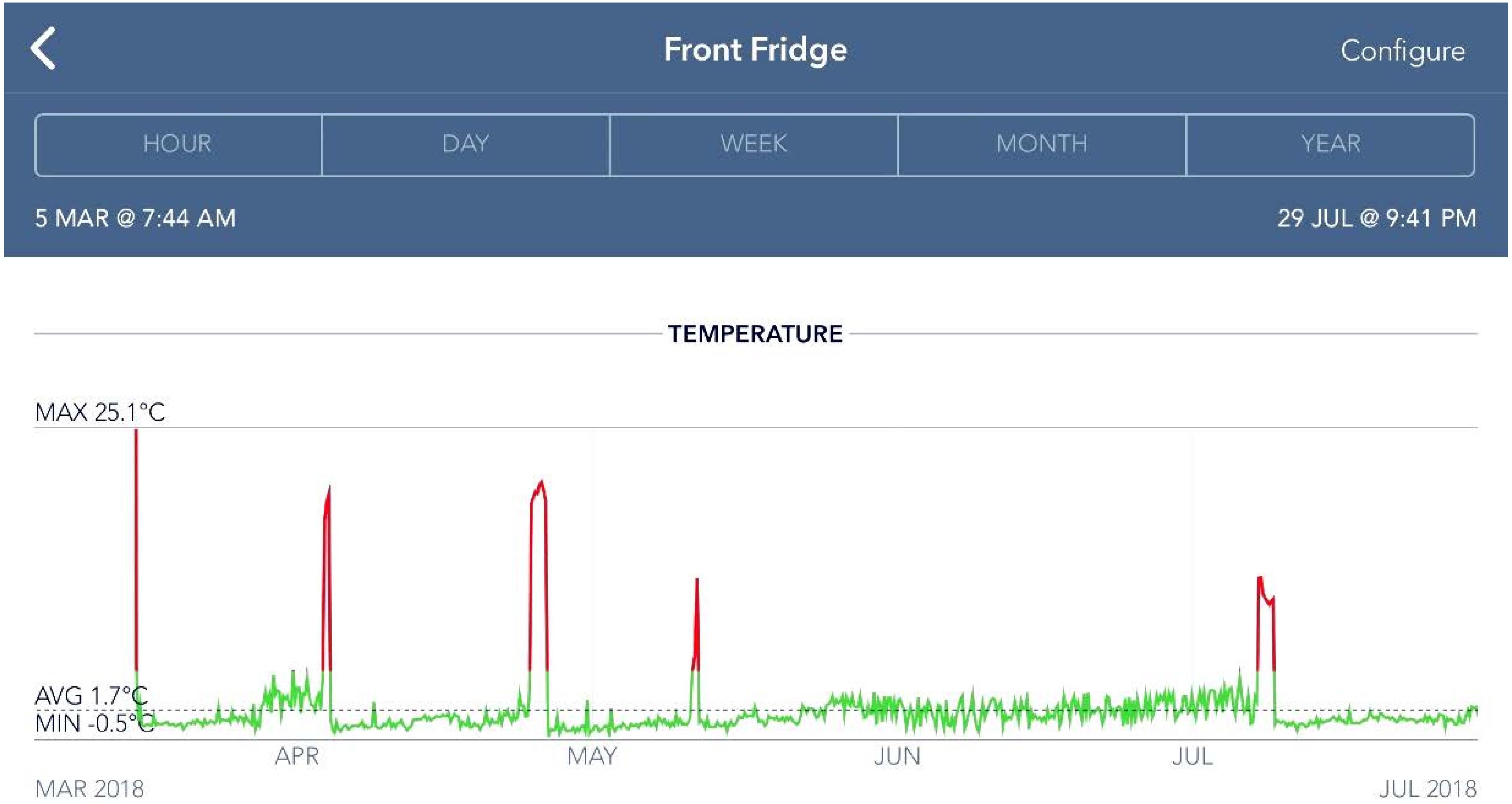

Figure 20: Temperature profile of front fridge

Figure 20 above shows the temperature profile for the front fridge located inside the butcher store. The sensor recorded an average temperature of 1.7^{o}C within the refrigerating equipment. Minimum temperature observed was -0.5^{o}C while a maximum temperature of 25^{o}C was recorded. More than 4 spikes in temperature above the maximum limit of 5^{o}C were recorded in the intervention period, and they ranged from between 19^{o}C-25^{o}C. No specific reason was provided by the butcher regarding this temperature spikes. However, this front fridge had been mentioned during the interviews as potentially defective in maintain cooling condition below 5^{o}C (See Section 6.3.3.4.4.3).

6.4.3.2 CONSUMER MEAT VERIFICATION

Figure 21 below shows the google play analytics results for the number of consumers who installed the app advertised in the butcher store during the intervention period. In the pilot case (Lamb) that occurred between Oct 1^{st} -Nov 1^{st} 2018, 8 consumers installed the meat verification app on the Android platform. No consumer installed the app on the Apple iOS platform (See Appendix M). During the final implementation case (beef) that occurred between November 1 to Dec 30, a maximum of 9 customers installed the app on their mobile phone using their Android devices. No consumer with iOS devices downloaded the app or scanned the QR code.

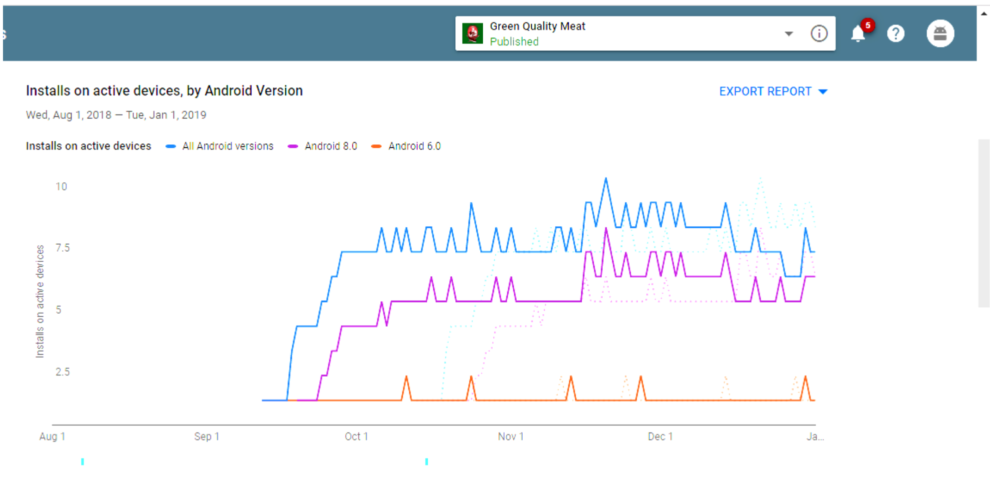

Figure 21: Number of consumers with active devices that installed the Android mobile meat verification application during the intervention period

Figure 22 below shows the number of customers that scanned the QR code and visited the webpage showing the traceability for the lamb and beef products, respectively.

Figure 22: Number of unique visitors who scanned the QR code

It shows that on October, 7 unique customers scanned the QR code to view provenance information for the lamb product. On November, 11 consumers scanned the QR code to view information related to the provenance of the beef product. In the month of December, only 2 participants scanned the QR codes for the beef products. **Figure 23** below shows the visitor analytics of consumers that interacted with the web page. Three crucial metrics used to examine consumer engagement on the web page include the number of users, sessions, bounce rate, and session duration. A total of 9 participants visited the web page during the intervention period. A bounce rate of 34.78% is also observed during the intervention period indicating that some level of user interaction with the web-app deployed online.

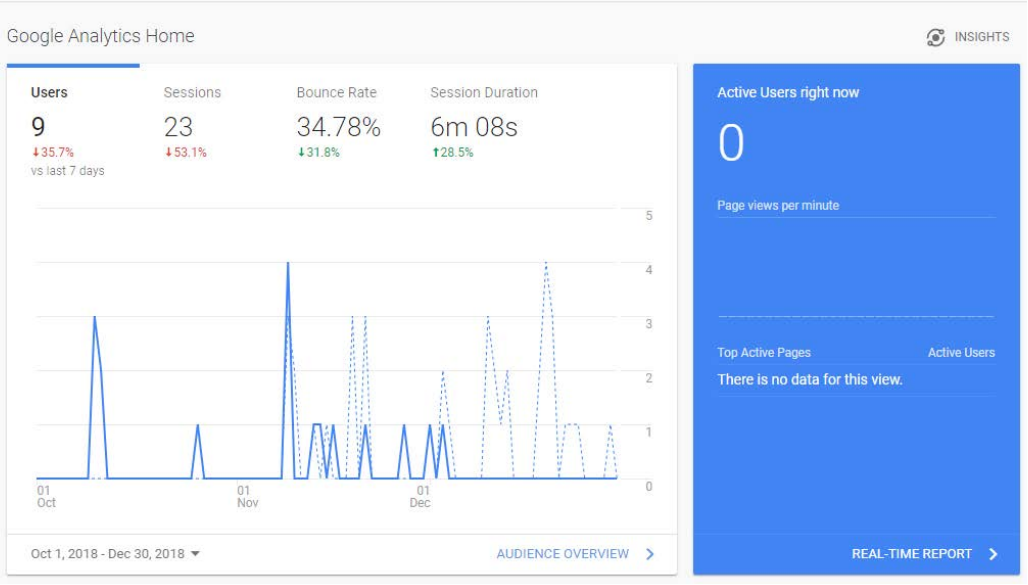

Figure 23: Visitor analytics data on the number of consumers that viewed the provenance information of beef and lamb product during the intervention.

6.5 PHASE 3: POST-INTERVENTION EVALUATION

In the post-intervention phase, the retail butcher was contacted to provide feedback regarding the role and potential impact of technology intervention on traceability within the supply chain segment. The interview focused on two key themes where the technology intervention occurred, namely: meat provenance and meat safety.

6.5.1 MEAT SAFETY

This theme presents the key findings from the retail butcher concerning the role and potential impact of sensor technology intervention on meat safety. The core categories that emerged are perceived role and impact of IT on *(a) organisational awareness and correcting staff behaviour; (b) visibility of cold chain operations; and (c) information quality*. The key findings that emerged under each core category s presented below

6.5.1.1 PERCEIVED ROLE AND IMPACT OF IT ON ORGANISATIONAL AWARENESS AND BEHAVIOUR

The participant believed that the sensor intervention played a role in *enhancing organisational awareness* regarding equipment performance of the fridge.

> *"Certainly well, my fridge goes in to defrost(laughs). Whereas I was not always aware of that, but um, we have got more defrost on the fridge now than we had before and we have had the fridge repaired in that time as well". (Participant P15).*

The participant also stated that sensor intervention played a role in monitoring and *correcting staff behaviour* in the management of *cold operations in the butcher store*.

> *"The staff, I did look, I did notice that and I say, and I mentioned it to him, like that - you make sure you keep the doors closed on the fridge. I just told the boys, and you know, look, then I can monitor to see whether or not they took it. But they took it on board pretty quick. There was only one instance like pinging, and we were like what is going on here?". (Participant P15).*

6.5.1.2 PERCEIVED ROLE AND IMPACT OF IT ON THE VISIBILITY OF COLD CHAIN OPERATIONS

The participant also stated that sensor intervention improved the *visibility and monitoring of cold refrigeration* operations in the retail store.

> *"Look, it's been handy to see where the fridge has been tracking all along, especially when like the fridges have been icing up and not defrosting.So we have been able to notice if the temperature is sitting up a little bit too high they might be a bit icy. So as far as maintaining the maintenance of our fridges and knowing when to defrost then and that it has been really good".(Participant P15)*

The participant stated that sensor intervention played a role in optimising *management decision regarding equipment maintenance for one of the fridges*.

> *"So the main things that we would have implemented would have been the maintenance of the fridge. Like um, maybe knowing that like if the fridge is working a little bit harder to turn it off and defrost that bridge. Like, because they do not get defrosted all the time, quite often they run all the time until the sensors entered". (Participant P15).*

The participant also stated that technology intervention played a role in *fault detection* for one of the chilling equipment in the cold room.

> *"I find the cold Room you know that it is maintaining its temperature, but the sensor was very touchy as far as like with our defrost went in like that, it will really ping me every 20 past 5 or 20 past 6 every morning. It was good. Like the cold room. We did have some trouble with the cold room. We had it serviced in that time as well as leaking some gas. But yeah, look, it was handy. Yeah. Like when you are thinking about those sorts of things to be able to go back and look at the actual hard data there, and know when something is tracking it all the time. It was very handy". (Participant P15).*

6.5.1.3 PERCEIVED IMPACT OF IT ON INFORMATION QUALITY

The butcher stated that sensor intervention enhanced the quality of temperature information.

> *"Well, I can access it 24/7. So like yeah, I will have more information there because I normally like quite often those defrost will be set when we are not in the shop. Yeah. So I can see that he is going into defrost. I can see that. Like it is working, it is pinging me, letting me know the fridge is working as it should be working".(Participant P15).*

6.5.2 MEAT PROVENANCE

This theme describes the perception of the retail butcher concerning what new role and potential impact did the mobile app intervention have on traceability in meat provenance within the supply chain segment. The core categories that emerged from the analysis are: (a) *perceived impact of IT on consumer awareness, product marketing; and (b) Technology utilisation and adoption success factors.*

6.5.2.1 PERCEIVED IMPACT OF IT ON CONSUMER AWARENESS AND PRODUCT MARKETING

The participant stated that the mobile verification app intervention enhanced his ability to market the meat product to customers visiting the butcher store.

> *"I just said look, we had got the Porters house here. This is the stake of the week, and this is some information if you scan this app, you can get some more information if you'd like to have a look? And they said sure yeah, we will have a look".(Participant P15).*

The participant also perceived that the mobile app intervention could potentially play a new role in enhancing the branding reputation of the butcher store.

> *"There were no follow-up questions other than like What is your app and like that and I said, yeah. I said it's a very basic app at the moment is being developed by a developer and could lead to a bigger thing. That's about it". (Participant P15)*

The participant also stated that the technology intervention in the store played a role in *enhancing consumer awareness and intrigue* regarding the new possibilities of verifying of the provenance of lamb and beef meat in the store by scanning the QR code. In terms of consumer.

> *"Some people were initially interested. Customers were initially interested. They scanned, and some of them took it away and scanned it at home.*

The participant stated that the mobile technology intervention raised *consumer intrigue* regarding the utilisation of an app-based verification system in the butcher store.

> *"Look, there was some intrigue as to do we have an app?" (Participant P15)*

6.5.3 TECHNOLOGY UTILISATION AND ADOPTION SUCCESS FACTORS

This theme describes the perception of the retail butcher regarding factors that may contribute to or inhibit the successful utilisation of the mobile app and sensor technologies in the butcher store. The core category that emerged is the *IT implementation approach and technology portability and ease of use.*

6.5.3.1 IT IMPLEMENTATION APPROACH (MOBILE APP INTERVENTION)

The participant believed deploying the mobile verification app at the point of sale would provide a stronger incentive for customers to utilise the app and scan the QR code while in-store as compared to providing consumers with a verification card to scan at home.

> *"Look at the point of sale, it [the app] is a good thing. To have it as a point of sale is a good thing because we could encourage people to do that. I think if it was a sticker, the same as any other APP as far as I am concerned unless there is some incentive to scan it, yeah people will not scan it, you know. So like the incentive was for us to encourage people to scan it. If I had not encouraged people to scan, I do not know". (Participant P15)*

6.5.3.2 TECHNOLOGY PORTABILITY (SENSOR INTERVENTION)

The participant believed that the portability of the wireless sensor intervention enhances it useability for monitoring temperature conditions in the store remotely.

> *"I think it is a handy piece of technology to know that, had that information on hand, we would have picked up on like the other things may have helped me pick it up a little bit earlier. It may have helped me pick it up just a little bit earlier. Um, so look it is a good technology. Um, to prevent a problem and it certainly allowed me to identify that problem earlier". (Participant P15)*

The participant also mentioned the following.

> *"The apps have been pretty easy to use. Yeah, it has been easy". (Participant P15)*

6.6 SUMMARY OF FINDINGS FROM SUPPLY CHAIN MAPPING, EXERCISE, BASELINE DATA COLLECTION, TECHNOLOGY INTERVENTION AND POST-INTERVENTION FOR CASE STUDY 2

This section presents a summary of the findings from case study 2. The research explored potential traceability challenges amongst small businesses operating in the post-slaughter segment of a red meat supply chain. A total of three participants were involved in this case study comprising of a *stock agent, wholesaler, and a retail butcher*. At the level of operations, the participants exhibited markedly different levels of traceability understanding concerning the beef product. While the stock agent and the wholesale believed they have sufficient knowledge of the provenance of their beef product, the retail butcher was unable t ascertain the traceability for the beef purchased. In prioritising traceability, the retail butcher did not perceive issues of provenance and animal welfare to be as critical to the business as compared to meat quality and meat safety. The stock agent prioritised all aspects of traceability because of the importance of ensuring that meat product sold satisfy client requirements and are safe for consumption. The wholesaler focuses more on safety as compared to meat provenance, meat quality and animal welfare because of the perception that most of his consumers are interested in price as compared to traceability.

After the supply chain mapping exercise, the feedback with each case study participants the revealed differences in their perception concerning the traceability challenges impacting their businesses along the chain. The stock agent and wholesale did not perceive any challenges concerning their traceability in areas that concern meat provenance, meat safety, meat quality, and animal welfare. As a result, both participants did not progress further to explore areas of improvement. However, the retail butcher perceived some challenges with regards to provenance and meat safety. And was interested in exploring improvement opportunities in the baseline data collection step.

Based on this analysis, baseline data collection conducted with the retail butcher. The assessment showed that the butcher perceived his level of visibility to be moderately high in areas of meat provenance and meat safety. In responding to some of the challenges faced, the research deployed a wireless sensor network temperature monitoring system (meat safety) and a meat verification app(meat provenance) to enhance the amount and quality of information that can be captured in the store.The technology deployment showed the feasibility of sensor and mobile technology implementation and the capacity for the technologies to play new roles in traceability in the butcher store. Technical data obtained from the meat safety intervention indicated that there were multiple spikes in temperature in the equipment above the threshold of $5^{o}C$. However, average temperature remained relatively stable during the intervention period. The meat verification app also revealed marked difference in consumer interactions with the mobile app. For example, the chart showed some consumer interaction with Android app while no activity for iOS app was obtained. In the post-intervention and evaluation, the key summary is that:

- The retail butcher believed that technology intervention played new roles in traceability in positively positive impacting areas of visibility and organisational operations. in areas of meat provenance and meat safety.
- The retail butcher perceived some positive impact of the mobile technology intervention on information quality, visibility of cold chain operations, and organisational capacity to respond to potential risks in the cold chain operations.
- The retail butcher believed that important technology success factors should be considered in facilitating the successful utilisation and potential adoption of the system in the store, and the include the location of technology deployment and portability of technologies.

Chapter 7

Analysis of Findings:
Case study 3

7.1 INTRODUCTION

This chapter presents the findings that emerged from the analysis of field data for case study 3, a lamb supply chain aligned to retail butcher 3 operating within the Tasmanian red meat industry. The presentation is organised in 3 parts, and these are pre-intervention (supply chain mapping and baseline data collection), technology intervention and post-intervention and evaluation. The breakdown of the section of the analysis chapter is as follows. **Section 7.2** presents an overview of the key findings that emerged from case study 3. **Section 7.3** presents the analysis of key findings that emerged from Phase 1-pre-intervention (step 2-supply chain mapping and step 3-baseline data collection). **Section 7.4** presents the analysis of key findings that emerged from Phase 2-technology intervention. The key findings from **Phase 1 and Phase 2** will provide answers to **Research Question 1**: *How can low-cost mobile technologies be utilised and deployed amongst small businesses in red meat supply chains to support traceability, and for responding to challenges faced?* **Section 7.5** presents the analysis of findings for phase 3 post-intervention phase. The key findings from **Phase 3** will provide answers to **research question 2**: (a)*What criteria do small businesses in red meat supply chains use in evaluating the role and potential impact of low-cost mobile technologies in supporting traceability, and for responding to challenges faced*?; (b) and **research questions 3**: How *can a small business traceability framework be developed to support the implementation and evaluation of low-cost mobile technologies to support traceability, and for responding to challenges faced?* .**Section 7.6** summarises the key findings from the chapter.

7.2 OVERVIEW OF KEY FINDINGS FROM CASE STUDY 3

Case study 3 is a full lamb meat supply chain that comprises of 3 small businesses. These include *farmer/lamb transport, meat processor, and cold transport/retail butcher*. A total of 4 participants were interviewed in this case study, and they include 1 farmer (P09), 1 wholesaler (P14) and 2 joint owner-managers at the retail butcher (P16 and P17). In step 2- supply chain mapping, all 4 participants were interviewed. After the mapping exercise, each participant was contacted to discuss the traceability challenges faced in their organisational operations and to obtain feedback concerning their willingness to explore areas where low-cost mobile technologies can assist in responding to some of these challenges. This required each participant to progress to step 3 (baseline data collection); phase 2 (technology intervention) and Phase 3 (Post-intervention). However, only the meat processor (Participant P13) and one participant from the retail (Participant P16) agreed to progress further in the study. However, the meat processor was not interested in participating in baseline data collection (Step 2) but was willing to experiment with some new technologies (Phase 2) and to providing feedback concerning the role and potential impact of the technology in the abattoir operations (Phase 3). One participant in the retail butcher participated in both baseline data collection (Participant 16*)*. Thus the analysis of findings in baseline data collection step (step 3) focuses on the retail butch along, while analysis of findings in Phase 2 (technology intervention) and Phase 3 (post-intervention) focuses on the meat processor (Participant P13) and retail butcher (Participant P16). The key finding in the supply chain mapping step is as follows:

1) In Phase 1 (Step 2-supply chain mapping), the industry participants exhibited marked differences in perceived traceability challenges impacting the lamb meat supply chain. For example, the farmer did not perceive any significant challenges with existing traceability practices in areas of provenance, meat safety, meat quality and animal welfare, and as a result, did not progress to Phase 2 and Phase 3 of the study. The meat processor, although exhibited similar perceptions as the farmer, opted to explore the role of low-cost mobile sensing technologies to support traceability in the abattoir in areas of provenance and meat safety without participating in the baseline data collection phase. However, the retail butcher raised multiple concerns and issues concerning traceability practices along the lamb supply chain, specifically in the area of meat provenance and meat safety. In phase 1 (Step 3-baseline data collection), the butcher perceived his level of visibility to traceability challenges to be of relatively low levels along the lamb meat chain with visibility scores of 2.8 out of 5 (meat safety) and 1.82 out of 5 (meat provenance).
2) In Phase 2 (technology intervention phase), 4 mobile technology interventions were deployed at different points of the lamb supply chain, particularly within the meat processor and cold chain/retail butcher segment

of the chain. The intervention also illustrates how low-cost mobile technologies can be deployed to support new roles in traceability for responding to traceability challenges of meat provenance (i.e. of identity preservation and meat verification) and meat safety (cold chain monitoring and verification) along the chain.

3) In Phase 3 (post-intervention phase), there were marked differences in how the industry participants perceived the role and potential impact of information technology on traceability in their business operations. For example, the participant at the meat processor could not see any significant benefit of the technology intervention on traceability within the abattoir, including the role and impact. However, in the retail butcher, the participant confirmed new roles of the mobile technology traceability, particularly in areas of consumer awareness and food safety assurance.

The next section below presents a detailed analysis of the key findings from Case study 3.

7.3 PRE-INTERVENTION (STEP 2: SUPPLY CHAIN MAPPING)

7.3.1 LAMB FARMER

Participant 09 is a farmer that specialises in raising prime lambs and cattle for local butchers and premium restaurants in Tasmania. The farm has been operational for the 124 years, and the business has continued through the family line to the current owner (Participant P09). Two main types of lamb breeds are raised in the farm, and these include the English Lester and the suffix or "south down lambs".

7.3.1.1 OPERATIONS

The participant performs 5 key activities in the farm production/transportation phase, and these include: (a) *growing new lambs; (b) weaning; (c) feeding/grazing; (d) vaccination; (e) and transportation* to the processor. In the growing phase, new rams are purchased from local stockers, and they are grown out on the farm. In some cases, the participant also mentioned that stocks are sourced from the mainland. In the weaning phase, the newly born lambs are separated from the mothers, ear-tagged, and vaccinated against such as scabby mouth, tetanus, cheesy gland and pelvic kidney.

> *"When they are six, six weeks to eight weeks old, they get marked. So that is when they get vaccinations, you know, for scabby mouth and tetanus and cheesy gland and pelvic kidney and all those diseases. They get another vaccine when they are about 12 weeks old or probably when they are three months older; so they get a drench for worms, for internal parasites".(Participant P09)*

Other activities, including monitoring of lambs to ensure that they are upright and not trapped in thorned bushed. The female lambs (ewes) are continually monitored in the farm to ensure that they do not face birthing difficulties In the feeding/grazing phase, the lambs are pasture-fed and are allowed to roam on the farm freely in the farm. These activities are performed routinely to maintain high standards of welfare on the farm. Once the lambs are grown out to 4-5months old, the lambs can be sold to clients which comprise of local butchers, restaurants, or private farms for further growing out. In the transportation phase, the farmer transports the lambs to the meat processor on behalf of clients for slaughtering and processing. The participant stated that the lambs are only transported in groups so that they can be in a familiar environment before their slaughter. The participant stated that providing a comfortable experience for the lambs before their slaughter because it can minimise the risk of stress and reduced meat quality.

> *"And I always transport more than two. At least two sheep. So I will never just take one shape to the abattoir because I think that's very stressful. They need company, and they need to be with, with their friends. So I think that is kind of document, you know, MLA has done, people have researched on all that kind of stuff. You cannot just put one sheep in with other sheep that it has never met before because it is extremely stressful for them" (Participant P09)*

7.3.1.2 TECHNOLOGIES

The key technologies utilised include NLIS tag for unique identification, laptop computer, mobile phone, and digital scales. The NLIS tag is utilised for unique animal identification. The laptop computer is being utilised for managing accounts and invoices. The mobile phone is used to facilitate communicating with other actors in the chain, including private consumers. The digital scale is used to measure the weight of the sheep, and to monitor the estimated growth performance.

> *"And, and that's why we're, we've just bought some scales because we want to be more switched on, more, more aware of, you know, how much does that lamb weigh, um, you know, how*

> *can we get it up to weight, how can we look after it better and, you know, get, get more money. So, you know, they are digital scales and kind of fancy three-way drafts scales. I do not know how I am going to work them". (Participant P09)*

7.3.1.3 INFORMATION

The key traceability information captured within the farm includes the PIC number, RFID tag number for the lambs and cattle, and the NVD information which includes important data elements such as sender name and address, receiver, breed, sex, age of the lamb, and veterinary care information. The farmer also mentioned that capture of feedback.

> *"We do have documentation. So from the Abattoirs. So from TQM where we sell a lot of our meat, we have whatever you call it, we have paperwork that's, that tells us, you know, how many lambs, what weight they were, what price we got paid. So that is all somewhere, but it is not easily accessible". (Participant P09)*

7.3.1.4 POTENTIAL TRACEABILITY CHALLENGES

The interview in this section focused on understanding the potential traceability challenges impacting the lamb production operations in the supply chain and the current role of IT. The core categories that emerged from this analysis relate to issues of meat *provenance, meat safety, meat quality, and animal welfare.* The key findings that emerged from these core categories are presented in the next section.

7.3.1.4.1 MEAT PROVENANCE

The participant does any traceability challenges with the ability to ascertain the provenance of the lambs because of their registration *to NLIS* from birth and the ability to trace their history through the NVD.

> *"Uh, will Yes. In terms of we have, we have our property identification code, we have our ear tag, and we fill out a vendor declaration form. So, um, yeah, every time sheep leaves, then the paperwork is filled out".(Participant P09).*

7.3.1.4.2 MEAT SAFETY

The participant does not perceive any traceability challenge with meat safety because *a paper-based documentation system* there is a paper-based documentation system that is utilised to record all *veterinary inputs* used to treat the lambs during their lifetime.

> *"I am just starting a system now of, of um, um, yeah recording it in a better way. So just starting to record now. So when they get their vaccination, you know, what dosage did they get, what is*

> *the batch number of the vaccine, you know, when does it expire? All that kind of stuff". (Participant P09)*

7.3.1.4.3 ANIMAL WELFARE

The participant does not perceive any traceability challenges with animal welfare as this is considered the key focus of farm production operations. The participant believes that the traceability of animal welfare is linked to *environmental sustainability*.

> *"So I kind of say I say ethical and sustainable because of what we do on the farm because we have been planting trees for 30 years, we are improving the landscape with more stock shelter. It means that there are more increased lambing percentages because the sheep have shelter protection from the cold wind and, and happy. Well you know, very well looked after, you know, I think our standards of animal welfare are very high. So I end up very, very exhausted because I spent all my time making sure that everybody's". (Participant P09)*

The participants also added the following.

> *"Oh yes, yes, yes. We are planting trees, restoring the landscape, providing shelter and, and it's. Also, it's about biodiversity. So it is just being a sheep farm but being able to farm with Tasmanian wildlife with the birds and the devils and the quolls". (Participant P09)*

The participant's motivation to enhance traceability in animal welfare is linked to the perceived opportunity for product marketing and differentiation, and educational attainment.

> *.I'm working at how we can all live together because that is quite, that is actually quite a big selling point, and it is important for me because that is just. I'm trained in science and I'm an ecologist". (Participant P09)*

The participant did not perceive any traceability challenge with animal welfare in road transportation because she engages in the private transportation of the lambs. This focus on animal welfare during road transportation is also partly motivated by perceived opportunity for product marketing and branding.

> *"That I am five minutes drive from an Abattoir, which is very nice in terms of a less, less stressful animal. That is another selling point too". (Participant P09)*

7.3.2 MEAT PROCESSOR

The meat processor is local service kill abattoir operating in Gretna, Tasmania. The owner-manager (Participant P13) was interviewed in this case study. The abattoir has been in operation for more than engages in meat for private clients, local butchers, restaurants, and local farmers. The range of meat products processed in service kill operations within the abattoir include sheep, beef, pigs, goats, deer, and rabbit. The mapping of the organisational traceability practices for the meat processor is presented in appendices (Appendix N). The next section presents the analysis of the key findings from the mapping exercise in the meat processor.

7.3.2.1 OPERATIONS

The meat processor is engaged in 5 key activities are performed by the participant in the meat processing phase, and these include *booking, receiving of livestock, processing, chilling, and loading.* In the booking phase, booking orders are placed in two ways. The first involves a call in by the clients (i.e. farmers) "to place a booking order.

> *"Most of the time, the farmers are bringing their stock to us. We then slaughter it on behalf of them and then cut it up to their requirements and then they take it home". (Participant P13)*

The second involves emergency delivery to the abattoir during working hours.n this instance, depending on time and schedule of operations, the animal could be processed on the same day.

> *"Yeah. Sometimes people do not even ring; they just run up with their stock and drop it off".(Participant P13)*

Once the booking is in place, the butcher mentions a processing order form is delivered to the client or read out via the telephone. A copy of the booking form is shown in the appendices (See Appendix O). The form contains standards sets of meat cuts that can be processed and the client could either tick off the forms or provide consent regarding their preferences over the phone, and the processor completes the order. In the receiving phase, the farmer delivers the livestock to the processor, and they are loaded into the lairage area where they are allowed to rest before slaughter. The butcher mentioned that some of the livestock that arrive at the abattoir might have lost lifetime traceability due to the loss of the RFID tags assigned to them.

> *"Yes. Sometimes animals come, and the tags have been ripped out of the ears by branches or fences".(Participant P13)*

The entire process of slaughtering of livestock to chilling of finished carcase differs for both cattle and groups of lambs. Processing of meat takes about 20mins per animal and then chilled for some days, depending on the type of carcase. For beef orders, estimated processing duration from receiving, processing, chilling and dispatch is 7 days for cattle and 3 days for lamb. The carcase is allowed to chill for a minimum of 3days after slaughtering.

> *"Well, a beast (cattle) normally takes probably about 20 minutes from the time it is alive to the time it is hanging in the fridge. And lambs normally take about the same time, only because we do 12 lambs at a time. So by the time we killed the first one and by the time we process them all and get it in the fridge, it's probably 20 minutes for that lane as well".(Participant P13)*

During the chilling phase, each carcase is identified with a tattoo mark, and this can either be registered to the name of the clients (e.g. farmer or butcher), or an internal tattoo mark owned by the meat processor. In the pickup and delivery phase, the clients to whom the sheep have been sold to call the owner of the abattoir to arrange for pickup. The participant mentioned that the cold chain delivery process could be handled by a third-party carrier or the customer.

> *"So 90 per cent of his time it is by themselves, or the other 10 per cent is by a carrier".(Participant P13)*

In summarising the foci of operations in the meat processor, the participant believes that maintaining meat safety is the most critical part of the businesses and this involves maintaining proper care and handling of the animal before slaughter and ensuring proper hygiene the conditions during meat processing.

> *"It is more about food safety, making sure that we process the carcass and then it is nice and clean and that the animal is nice and healthy as well. It is more about food safety". (Participant P13)*

7.3.2.2 TECHNOLOGIES

The meat processor utilises some IT to support abattoir operations. These include, the key technologies are these include an RFID scanner, desktop computer, printer and a laptop.

> *"Basically, we have just got the NLIS scanner (machine), desktop computer, printer, laptop". (Participant P13)*

The desktop computer is utilised for digitalisation of NVD records and updating the records on the NLIS database over the internet. The RFID scanner is used to scan and register the NLIS ear tags affixed to the animals during their arrival at the plant. The tags are individually scanned, and traceability information is updated to the NLIS database.

> *"What we do is we basically cut out their tags off after they have been killed and then bring them in here. So we have the machine inside the office, and we can just scan them here, send the information off straight away". (Participant P13)*

The printer is used to print out receipts for clients. The mobile phone is the primary means of communication with clients and consumers that are bringing their stocks for service kills.

7.3.2.3 INFORMATION

The critical information of lamb traceability is captured within the RFID tag, PIC number, and NVD document. The participant stated that NVD information is received only when the animal is delivered to a third party. However, for those animals that are consumed by the farmer or privately for other clients, the participant stated that no NVD form is provided by the farmer.

> *"Not, not if it is for their own consumption, they do not. But if it is for other people. Yes, they do".(Participant P13)*

7.3.2.4 POTENTIAL TRACEABILITY CHALLENGES

The interview in this section focused on understanding the potential traceability challenges impacting the abattoir operations in the lamb supply chain and the current role of IT. The core categories that emerged from this analysis relate to issues of meat *provenance, meat safety, meat quality, and animal welfare.* The key findings that emerged from these core categories are presented.

7.3.2.4.1 MEAT SAFETY AND ANIMAL WELFARE

Two sub-categories emerged from the participants perceived potential traceability challenges related to meat safety and animal welfare, and they are **compliance and limited value proposition**

7.3.2.4.1.1 COMPLIANCE

The participant does not perceive any traceability challenge with meat safety because the DPIPWE conducts routine inspections and auditing of meat safety practices in the abattoir.

> *"That is all in the audit as well. But we do have random dropping from biosecurity. We get audited twice a year. We probably get four random droppings as well". (Participant P13)*

The participant also stated that he does not perceive any challenge concerning the traceability of animal welfare because it is covered in routine inspections conducted by the DPIPWE.

> *"Normally, they come, biosecurity comes to see how we handle the animals, make sure that we are doing the correct stunning techniques, and when we do our audit, and it is more about the cleanliness and the way we process the animals and all that." (Participant P13)*

7.3.2.4.1.2 LIMITED VALUE PROPOSITION

In terms of the role of technologies, the participant stated that he is aware of some technologies that could be deployed to enhanced traceability in temperature information in the abattoir. However, he believes it is beyond the scope of the abattoir operations.

> *"You can do a lot of things. I can put an alarm on my cool room, so if any of the cold rooms go off it sends me an alert to my phone, but no, I do not think I will go that far". (Participant P13)*

7.3.2.4.2 MEAT PROVENANCE AND MEAT QUALITY

One sub-category emerged concerning participant's perceived traceability challenges in the area of meat provenance and meat quality within the abattoir, and these are **perceived compliance and cost of implementing new IT, and transparency to meat quality information.**

7.3.2.4.3 PERCEIVED COMPLIANCE AND COST OF IMPLEMENTING NEW IT

The participant does not perceive any challenge with ascertaining the provenance of meat because all animals that arrive at the abattoir are registered to NLIS to update lifecycle information after slaughter.

> *"I just normally scan their ear tags when they have them, and send off the information".(Participant P13)*

Regarding the role of technologies in provenance, the participant believes that the cost of implementation significantly outweighs the benefit of enhanced traceability in the abattoir.

> *"We could go a little bit further and get another machine linked up to a computer, and we can put in. So when tags come out, like*

the big rabbit doors, the tag will come out and say the date, the time, and who owns it when it was killed and how much it weighs, but you know, who wants to. I do not want to fork out another $10,000 for that. Yeah, I'll do it all manually. Just write it in a book".(Participant P13).

7.3.2.4.4 TRANSPARENCY TO MEAT QUALITY INFORMATION

In the area of meat quality, the participant also stated that he does not perceive any traceability challenges. Two critical information captured with regards to meat quality, and these includes colouration and fat content.

"I normally look at the colouration, amount of fat, and that is it."(Participant P13)

7.3.3 COLD CHAIN/RETAIL BUTCHER

Two participants (P16 and P17) were interviewed in the cold chain/retail butcher segment of the lamb supply chain. Both participants are joint owner-managers of the butcher store and perform different key functions. The first participant (*Participant P16*) is the manager of the store and performs key operations such as sourcing of produce, cold chain transportation, wholesale delivery, general retail and oversees management issues surrounding the operations of the store. *Participant P17* is a co-owner of the store and handles the accounts, marketing, and payroll for staffs working in the store. The local retail butcher store sells a range of meat products which includes beef, pork, lamb, venison, game, rabbits, poultry, crocodile. The butcher also sells customised meat product to consumers with specific religious and dietary requirements such as halal, gluten-free, and paleo diet. This study focused on the lamb supply chain, which is part of the post-slaughter segment of case study 3. The mapping of organisational traceability practices is presented in the appendices (Appendix N). The analysis of the findings from the supply chain mapping is presented in the next section below.

7.3.3.1 OPERATIONS

The retail butcher store is engaged in at least four key activities, and these are include *sourcing/ordering of meat products, cold chain transportation, chilling, display and retail sale*. In the sourcing/ordering phase, the butcher contacts the lamb farmer (Participant P09) to place new stocks order for lambs. The farmer prepares the lambs for despatch, and they are privately transported to the meat processor (Participant P13). Once the carcase has been processed, the butcher is contacted by the meat processor to arrange for the pickup of the lambs. In the transportation phase, the butcher store operates a private cold truck that is utilised to pick-up delivery orders from the abattoir and despatched to the butcher store. In the retail, the lamb products are unloaded, chilled and dis-aggregated into different meat cuts for display and consumer sales. In the sale phase, one participant stated that for most consumers the decision to purchase meat is aligned to meat quality and then followed by origin.

> *"They want something that they are going to eat really well, is probably number 1..then it would be the origin (), like to associate the area you know its what they perceive, in their heads that is what they think" (P16)*

7.3.3.2 TECHNOLOGIES

The butcher store has implemented some IT tools to support traceability and retail operations. These technologies include the use of wireless internet, a mobile computing system, portable and wireless temperature sensor network, product labelling and identification technologies, and social media accounts. One participant describes the role of IT in the butcher store as follows.

> *"So we have NBN, we have node phones that go with the NBN, we have a point of sale which is computerised, and I use TeamViewer to log in to the computer to take over the shop computer so that I can do the bookwork from home. We have our accounting package, which is Xero so that I can logon anywhere even if I'm overseas or not I can logon and work up to date and put the pays through".(Participant P17)*

The retail butcher store owns a website that provides general information for customers regarding the business, cooking style for different cuts of meat sold in the store, and provenance. (See Appendix Q). As part of maintaining a digital presence, the store also owns a social media account that plays a role in consumer engagement.

> *"We have tried things in the past either with on facebook or Instagram. We have also done a test message for Christmas orders, reminders, so for like these are our opening hours or your order number. So it is for call to action, so do not forget to pick up your Christmas order, your order number is "dat dat dat". (Participant P17)*

7.3.3.3 INFORMATION

The key information received by the butcher includes a tattoo identification mark on the lamb carcase. During road transport, no information related to temperature condition of the truck is captured. In the retail store, the fridge sensors generate new temperature data, and this is communicated to the butcher as text messages to the mobile phone. No carcase identification label is linked to the lamb from the abattoir.

7.3.3.4 POTENTIAL TRACEABILITY CHALLENGES

The interview in this section focused on understanding the potential traceability challenges impacting the retail butcher operations in the lamb supply chain and the current role of IT. The core categories that emerged from this analysis relate to issues of meat provenance to meat *provenance, meat safety, meat quality, and animal welfare*. The key findings that emerged from these core categories are presented in the next section.

7.3.3.4.1 MEAT PROVENANCE

One sub-category emerged from participants perceived potential traceability challenges of meat provenance, namely **access to product traceability information and issues of information quality**.

7.3.3.4.1.1 ACCESS TO PRODUCT TRACEABILITY INFORMATION AND ISSUES OF INFORMATION QUALITY

One participant mentioned that for most of the meat products sold in the store, knowledge of their traceability could be ascertained.

> *"Most of this stuff, we have a rough idea of where it normally comes from" (Participant P16)*

However, with the lamb meat, the participant stated that there were some challenges with the timeliness and access to information concerning the provenance related enquiries with the farmer

> *"Yeah, we will like a bit more information, especially with lambs or instantaneous information will be handy. So rather than ring up to say can you follow it up? Or have you got it? like how old, what type of breed, what he has been eating? (Participant P16)*

7.3.3.4.2 MEAT QUALITY

One sub-category emerged from participants perceived potential traceability challenges of meat quality, namely **consumer interest in meat quality information.**

7.3.3.4.2.1 CONSUMER INTEREST IN MEAT QUALITY INFORMATION

One participant stated that some consumer asks for more information on meat quality and that the information is passed along to them verbally.

> *What type of breed. How is it treated? Specific cuts, how old it is, sex, whether it is the left or the right leg walking away. Yeah,*

some people are very specific to know which side of the body it is from(P17).

The same participant added

"Just tell them the truth. Verbally. Primarily verbally" (P17)

7.3.3.4.3 MEAT SAFETY

One sub-category emerged from participants perceived potential traceability challenges related to meat safety, namely the **use of traceability technologies.**

7.3.3.4.3.1 USE OF TRACEABILITY TECHNOLOGIES

The participants did not perceive any challenges with their capacity to ascertain the temperature condition of the meat in the chilling rooms because the store has implemented a temperature sensor network for wireless monitoring.

"Yeah, we have fridge sensors are linked back to our LAN system, and they send a text message if they go up to certain parameters to xxxx' phone" (Participant P17)

Another participant also stated the following

"We also have a temperature scanning device. we do have digital thermometer as well that you can back up with the USB. ".(Participant P16)

7.3.3.4.4 ANIMAL WELFARE

One sub-category emerged from participants perceived potential traceability challenges related to animal welfare, namely **customer responsiveness.**

7.3.3.4.4.1 CUSTOMER RESPONSIVENESS

One participant stated that most of the consumers visiting the store are interested in understanding what veterinary inputs and chemicals have been used to grow the animal and the animal production technique

"Like how it was treated. How old is it? Like sort of like free-range? That applies to everything. if it is grain-fed or pasture-fed." (Participant P16)

In responding to consumer demand for animal welfare, the participant stated the following.

"if I ring up straight away" (Participant P16)

7.3.3.5 FEEDBACK FROM CASE STUDY PARTICIPANTS AFTER SUPPLY CHAIN MAPPING EXERCISE

As mentioned in Section 4.7, each participant was contacted after the supply chain mapping step was concluded to discuss and prioritise potential traceability challenges being faced in the chain. The aim was to obtain feedback from each participant concerning the perceived criticality of the traceability challenges faced and their willingness to progress to the next step (i.e. baseline data collection), Phase 2 (technology intervention), and Phase 3 (post-intervention).

However, the feedback received from each participant indicated marked differences in perceived traceability challenges, level of criticality to their business, and willingness to explore areas of improvement in visibility and traceability. The lamb farmer (Participant P09) did not perceive any traceability challenges with regards to issues of provenance, meat safety, meat quality and animal welfare. As a result, the farmer did not continue in the study but was willing to assist the butcher in providing new information on the provenance of lamb sold to the consumer. The participant from the meat processor (Participant P13) did not perceive any challenge with traceability practices and was not interested in progressing to step 2 (baseline data collection). However, the meat processor (Participant P13) was interested in experimenting with new technologies in phase 2 (technology intervention) in areas of meat safety (temperature monitoring) and provenance/meat labelling (carcase identification. In the cold chain/retail butcher segment, only one participant progressed further in the study. The participant (P16) perceived some challenges with traceability of the lamb in the area of meat provenance and was interested in exploring opportunities for enhancing the amount and quality of temperature information that can be captured along the cold chain using some low-cost technologies.

Based on the feedback received from each case participants, the research selected the retail butcher as the focal company for step 2 (baseline data collection). The focus was to assess the butcher’s perceived level of visibility to traceability challenges faced in areas of meat safety (temperature monitoring in the cold chain) and meat provenance (verification of lamb meat origin the farm). In Phase 2 (technology intervention) and Phase 3 (Post-intervention), both the retail butcher and meat processor participated. The next section presents the analysis of findings from the baseline data collection phase with the retail butcher.

7.3.4 STEP 2: PRE-INTERVENTION (BASELINE DATA COLLECTION) WITH RETAIL BUTCHER

Quantitative baseline data was obtained from the retail butcher to assess the current level of visibility to potential traceability challenges aligned to meat provenance and meat safety at different segment of the lamb supply chain. In the farm production phase, the butcher assessed his current level of visibility to information on the provenance of lamb products purchased from the farmer. In terms of meat safety, the butcher assessed his level of visibility to temperature along the cold chain. Table 15 below shows the butcher's perceived level of visibility to traceability challenges in meat safety focused on meat temperature information at the processor node. In terms of accessibility, the butcher believes that he has less than 25% access to information on temperature information in the abattoir. In terms of accuracy, the butcher believes that the temperature information provided by the processor is satisfactory, but that situations in which the temperature information is incorrect are not uncommon. In terms of freshness and currency of information, the butcher believed that temperature information could only be accessed in the meat processor is contacted. Based on the visibility formulae, node visibility score to on temperature information at the processor node along the lamb supply chain is 2.08 indicating an average level of visibility.

Table 15: Butcher's perceived level of visibility to traceability challenges of meat safety (meat temperature information) at the processor node

Prioritised traceability challenge (processor node)	*I have access to none or little (less than 25%) of information within the supply chain node*	*The accuracy of exchanged information is usually satisfactory, but situations in which the information is incorrect are not uncommon*	*information is updated only when I ask the processor to provide data*	*Node visibility*
	Accessibility	Accuracy	Freshness and currency	Visibility score
Meat safety	1	3	3	2.08

Table 16 below shows the butcher's perceived level of visibility to the provenance of lamb products. In terms of the accessibility to provenance information, the butcher scored the farmer 1 indicating that information is usually limited to less than 25% of the total information that can be captured and utilised to add value to the meat product. In terms of accuracy, the butcher scored the farmer 3, indicating that while information is satisfactory, there were situations where the accuracy of information could not be verified. In terms of freshness and currency, the butcher scores the farmer 2, indicating the information is provided when it is requested. Based on the visibility assessment of the butcher, total visibility score concerning meat provenance was calculated to be 1.82 indicating a below-average visibility level using the visibility formulae presented in Chapter 3 (Section 3.6.3.1, Table 10).

Table 16: Butcher's perceived level of visibility to traceability challenges of meat provenance at the lamb farm node

Prioritised traceability challenge (lamb farmer)	I have access to none or little (less than 25%) of information within the supply chain node	The accuracy of exchanged information is usually satisfactory, but situations in which the information is incorrect are not uncommon	Information is updated only when the farmer is asked to provide data	Node visibility
	Accessibility	Accuracy	*Freshness and currency*	*Visibility score*
Meat provenance	1	3	*2*	*1.82*

7.4 PHASE 2: TECHNOLOGY INTERVENTION

Following the baseline data collection step, the research held a consultative meeting with the retail butcher and meat processor to discuss low-cost mobile technology options that can be deployed in their organisational operations and along the supply chain to enhance visibility and capacity for traceability in areas of meat safety and meat provenance. Based on the meeting with both participants, 4 low-cost technology intervention was identified, selected proposed and deployed at different points in the lamb supply chain to respond to some of the critical traceability challenges faced in the chain.

In the meat processor segment, two technologies were deployed. The first technology involved the deployment of a carcase labelling system to enhance identification of the lamb carcase and to support traceability of the lamb up to the retail. The second intervention involved the deployment of a temperature monitoring system in the abattoir to improve transparency in meat temperature information in the chilling room.

In the cold chain/retail butcher segment, the research implemented two technologies. The first technology is a portable temperature tracking solution to maintain traceability of meat temperature from the abattoir till retail. The second intervention is the implementation of a mobile meat verification app to support verification of meat origin using a QR code scanning recognition device linked t the mobile app. The next section describes in detail the deployment of the technologies in different segments of the lamb meat supply chain

7.4.1 BARCODE LABELLING AND TEMPERATURE MONITORING INTERVENTION (MEAT PROCESSOR)

The first technology intervention involved the implementation of a portable SensorPush® mobile Bluetooth wireless temperature monitoring solution in the cold storage area of the abattoir (See Appendix R). The technology included the use of a SensorPush® Bluetooth temperature sensor, a mobile app installed on the participants (P11) Bluetooth enabled iOS device. The intervention took place between 6th October – 6th November 2018. The second intervention involved the implementation of barcode identification labels on 5 lamb carcase in the processor. The barcode labels were designed in consultation with the retail butcher and the meat processor. Both agreed to use a simple alpha-numerical convention (See Appendix S).

Figure 24 below shows a sample barcode identification label used in the experiment. The labelling convention, as suggested by the butcher utilised the first name of the store and a numeric code. A total of five carcase tags were generated and tagged to the lamb carcase. The labelling convention, as suggested by the butcher utilised the first name of the store and a numeric code (0001-0005) for each carcase. The protocol for the carcase labelling intervention was as follows. The researcher sent the 5 carcase tags to the abattoir for their identification on the 26th of October. A simple instruction was given to the meat processor (Participant P13) over the phone on how to apply the carcase tags to the processed lamb after slaughter. Once the tags arrived, the researcher contacted the retail butcher (Participant P16) to progress with placing new stocks orders for lamb. Then the retail butcher contacted the lamb farmer

(Participant P09) to place stock orders for five lambs on the 29th October 2018. The lamb farmer (Participant P09) processed the order and transported the lambs to the abattoir on the 30th Oct 2018. On arrival at the abattoir, the lambs were slaughtered on the same day. The five lamb carcase was tagged with the printed labels alone, and they remained in the chilling room till the 11th of November,2018 Pickup was arranged by the butcher on the 11th of November, and the carcases were delivered to the store on the same day by the retail butcher (Participant P16).

Figure 24: Barcode labelling tags used for the identification of carcase in the meat processor

7.4.2 PORTABLE NFC TEMPERATURE TRACKING SOLUTION INTERVENTION (COLD CHAIN)

The third intervention involved the implementation of 2 portable Blulog ® NFC temperature tracking sensor to track temperature along the cold chain. The sensor devices are shown in the appendices (Appendix T). The protocol for sensor intervention was as follows. The researcher initially activated two Blulog®Sensors in the abattoir on the 30th of October and installed in the cold room along with the SensorPush ®. The goal was to maintain temperature visibility between the meat processor, through the cold chain and finally to the retail butcher using the portable temperature sensor device. On the day of pickup by the retail butcher, the meat processor(participant P13) was instructed over the telephone to remove the Blulog ® sensors from the cold room in the abattoir and to place each tag on the labelled carcase to continue the temperature monitoring during logistics. The tags along with the sensors remained in the butcher store till final disaggregation and display on the cabinet.

7.4.3 MOBILE MEAT VERIFICATION APP (RETAIL BUTCHER)

The fourth intervention involved the implementation of a mobile meat verification system to enable the retail butcher to demonstrate the provenance of lamb meat to those consumers interested in learning more about the origins of their food. The verification and traceability system consisted of three technology components: (a) a native mobile application interface designed for both Android and iOS devices (b) a content management system for inputting data elements aligned to traceability of lamb meat, and (c) a front end interface for user verification and interaction. The user interfaces for each of the mobile application can be found in Appendices (Appendix U). The user interface was designed in consultation with the participants in the retail segment (Participant P16& P17). As part of developing the native mobile app for the consumer, the butcher provided contents and design pattern for the app in order to align the user interface with the brand/colour proposition of the store.

The mobile app contained information on the range of meat products sold in the butcher store such as Poultry, Beef, Lamb, Pork, Veal and Game. Each of the listed meat products was linked to internal pages where customers could view additional information regarding the quality and cut types. The front user interface of the consumer app consisted of two meat verification functionality, and these are QR code and the NFC verification. The QR code functionality allows the consumer to verify the traceability of the lamb by scanning the QR code of a product displayed in the store (See Appendix U). The NFC allows the consumer/butcher to retrieve information of the provenance as well as temperature profile for the meat product. The mobile web application system deployed on the web for consumer verification is shown in Figure 25 below. The key data elements utilised include the name of meat, barcode number, farm origin, date and time stamps (where specified) for actors involved with movement and transformation. In terms of meat quality, two data elements were captured, and these include: feed input and breed of the lamb. No RFID tag numbers were captured because the meat processor stated that the lambs did not arrive with RFID tags.

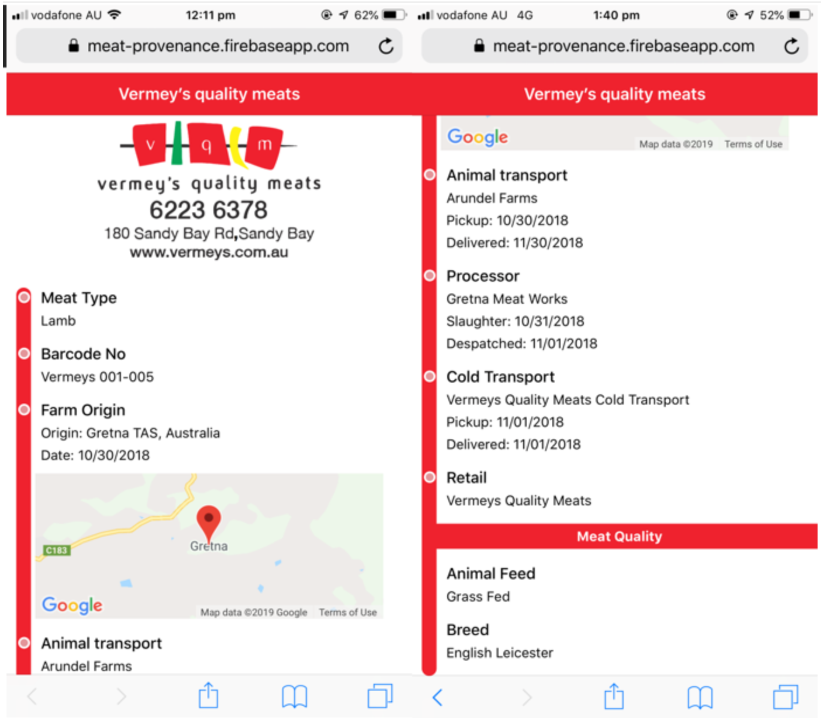

Figure 25: Mobile web application intervention for lamb provenance

7.4.4 ANALYSIS OF FINDINGS

7.4.4.1 BARCODE LABELLING AND TEMPERATURE MONITORING INTERVENTION (MEAT PROCESSOR)

Figure 26 below shows the temperature chart for the cold room obtained from the SensorPush ® dashboard within the intervention period between Oct 6th - November 6th, 2018. The green line is indicating that the temperature condition was below the maximum temperature limit of 5^{o}C. The red lines shown in the chart indicates that temperature condition in the cold store exceeded the maximum limit of 5^{o}C. The average temperature during the intervention period was 3.5^{o}C. A minimum temperature of 2.5^{o}C and maximum temperature as high as 14^{o}C was recorded respectively during the intervention period. The cold room temperature experienced 20 spikes in temperature above the maximum threshold of 5^{o}C. The meat processor (Participant P13) suggested that the temperature spikes above the maximum threshold could be due to normal defrost cycles or instances where the chilling room was not operational.

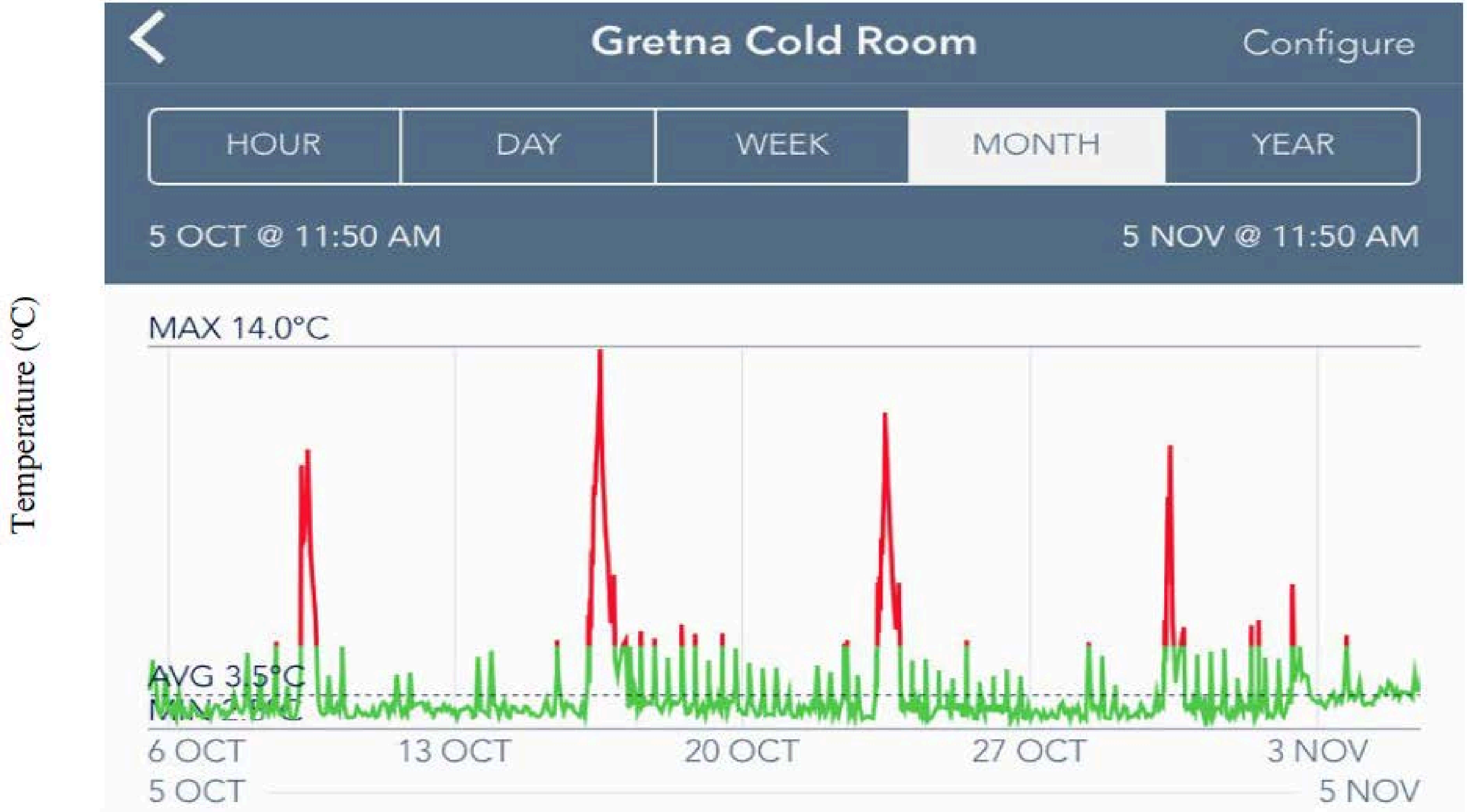

Figure 26: Temperature chart for the cold room in the abattoir

7.4.4.2 COLD CHAIN INTERVENTION

The temperature profile for the cold chain intervention between the meat processor and the retail is shown in Figure 27 and Figure 28 below. As seen in both temperature profiles, the sensors recorded at least 20 temperature spikes above 5°C in the cold room within the meat processor between the 30th Oct and 2nd November. However, the average temperature was below 5°C for the significant part of the intervention.

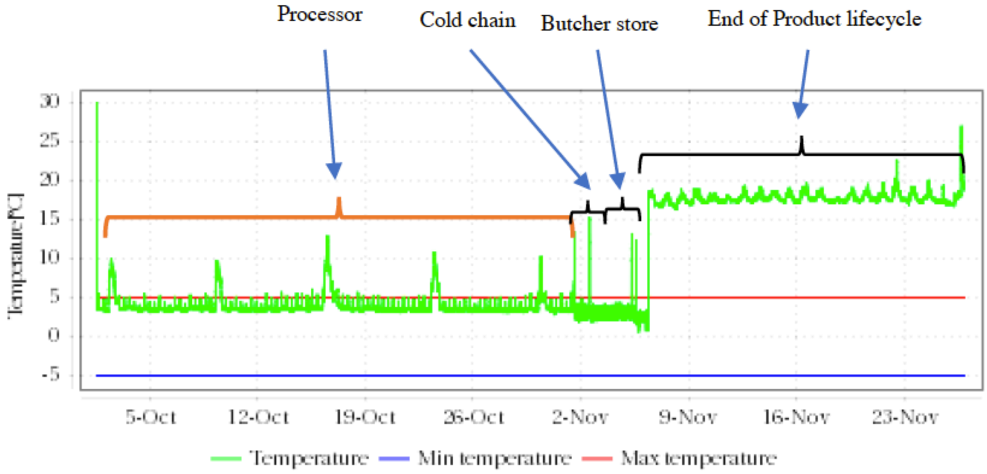

Figure 27: Cold chain transport temperature chart between the processor and the retail butcher

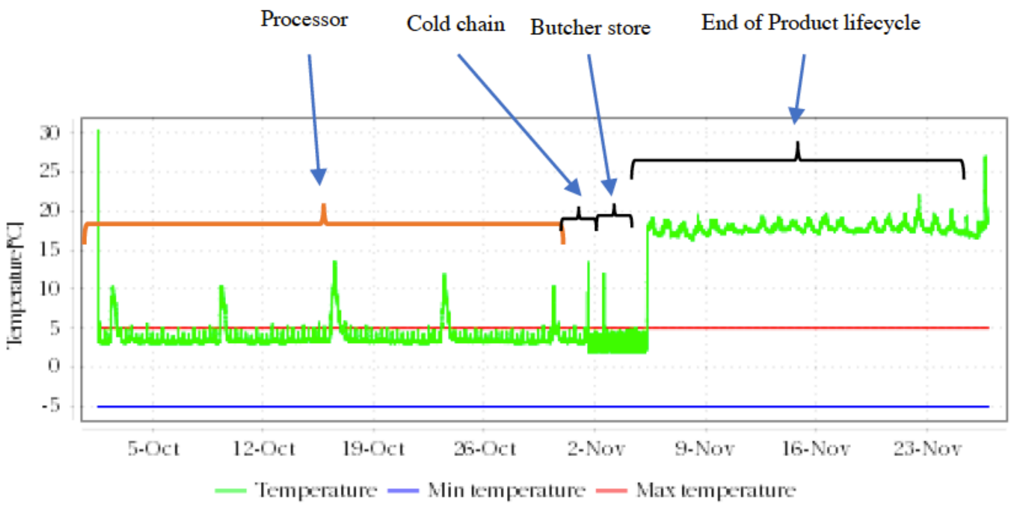

Figure 28: Cold chain temperature chart between the processor and the retail butcher

From the temperature charts above in Figure 27 and Figure 28, it can also be observed that on the 1st of November the retail butcher picked up the five lamb carcases and delivered the same day to the retail store. During transportation, temperature condition was stable at below 5°C, which occurred on the 1st of November,2018. The spike in temperature on the 2nd of November was suggested by the butcher to be the period of dis-aggregation of the carcase in the butcher store during occasional removal of the carcase from the storeroom. This would have exposed the lamb carcase to abnormal temperature condition consistent with reasonable climatic condition of the environment, thereby resulting in the occasional peaks observed in the period. However, the temperature remained at below 5°C in the butcher store cold room between the 2nd to 5th of November. Occasional spikes observed during the period represented the continual retrieval of the lamb carcase from the cold room for further dis-aggregation by the staffs until the end of its lifecycle. After the lambs have been completed, the butcher kept the sensors on the wall area of the store, and this explains the spike in temperature between 9th - 24th of November. The researcher picked up the sensors on the 26th of November,2018.

7.4.4.3 MOBILE VERIFICATION APP INTERVENTION

Figure 29 below shows the Google Play Console statistics of Android-based consumers that downloaded the native mobile application from the play store during the advertisement/intervention period. It shows that a total of 6 consumers downloaded the native mobile application from the Android platform. For the iOS platform, no consumer downloaded the mobile application (See Appendices V). Figure 30 below shows the consumer referral and visit statistics indicating the number of users that scanned the QR code and visited the provenance web app to learn more about the origin of the lamb meat product.it can be seen that during the advertisement campaign on the 2nd of November, 2 consumers visited the provenance web app to view the traceability information for the lamb products. On the 3rd of November 3, consumer visited the web app. On the 4th of November, 1 consumer visited the web app. Between the 6th-8th of November, only one participant viewed the website through the QR code. Between the 10th -25th of November, 8 more consumers visited the webpage to view the information related to the provenance of the lamb.

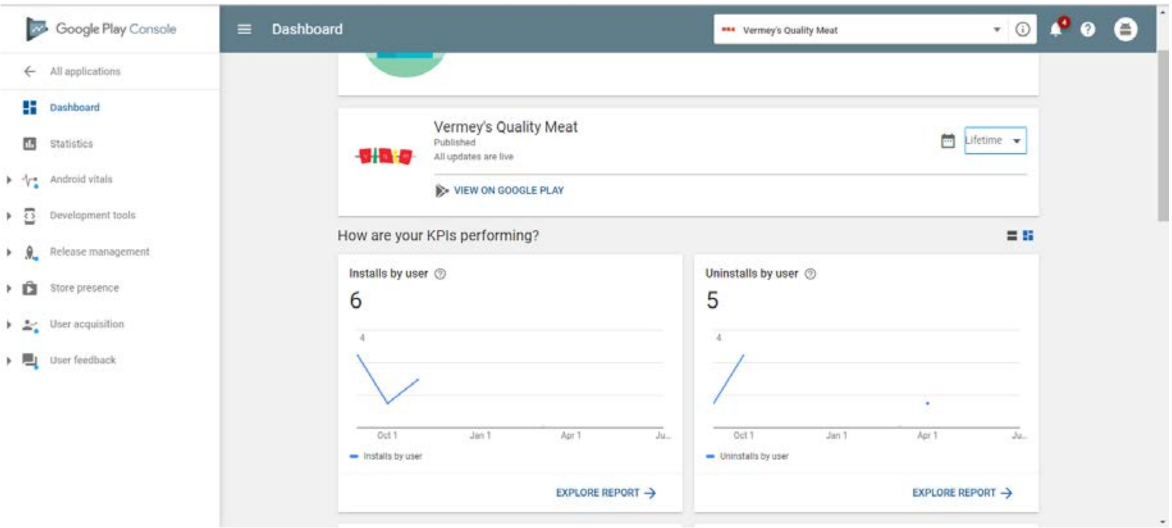

Figure 29: App download statistics for Android-based customers

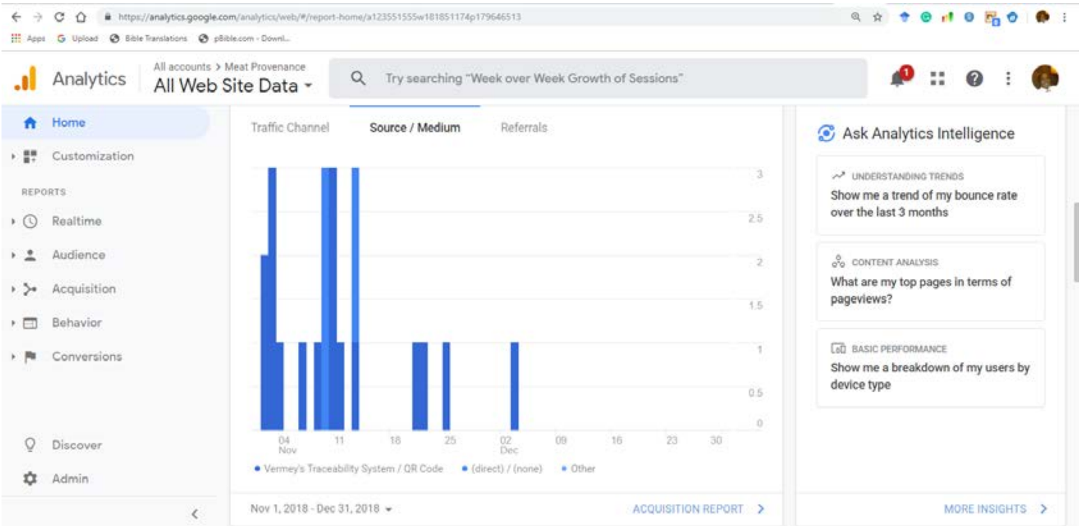

Figure 30: Consumer referral and visit statistics to the webpage showing the provenance of the lamb carcase.

7.5 PHASE 3: POST-INTERVENTION AND EVALUATION

In the post-intervention, the participant at the processor (P11) and the owner-manager of the retail butcher store (P14) were both interviews as part of feedback and evaluation to provide their feedback regarding the role and impact of the technology intervention in the supply chain. The key theme that emerged from the analysis of the feedback is the *perceived impact of IT on traceability*. The core categories under each category are presented in the next section below.

7.5.1 PERCEIVED IMPACT OF IT ON TRACEABILITY IN THE MEAT PROCESSOR

The theme describes the perception of the meat processor concerning the potential impact of the technology intervention on *provenance and meat safety*. The core categories are perceived the impact of IT on meat safety and perceived impact on the meat provenance. The details of each category are presented in the sub-section below.

7.5.1.1 PERCEIVED IMPACT OF IT ON TRACEABILITY IN THE MEAT PROVENANCE

The participant believed that the barcode labelling intervention had a positive impact on the capacity for carcase identification.

> *"We do not add any tags at all, but yes it would be helpful. As people want to know more about where their meat is from, it would be helpful, yes." (Participant P13)*

Although the participant expressed his intention to adopt the labelling solution, he believed that the technology *lacked suitability* with the *current foci of business operations*.

> *"I could add it to our business but because we only do private kill like for farmers. It is not as if we always kill for butcher shops. Another processor that kills mainly for butcher shops it could be useful for them". (Participant P13)*

7.5.1.2 PERCEIVED IMPACT OF IT ON TRACEABILITY IN THE MEAT SAFETY

The participant did not perceive any impact of the sensor intervention on the level of visibility and traceability of carcase temperature in the chilling room. In the opinion of the participant, the technology *lacked usefulness* with his *preferred method of processing operations*.

> *"Look I do not go into that much side of things. I am in and out of the fridge all day, so I sort of know when they are cold and not cold, so I do not really look at the app. So I know because I'm in there every day. So I know when its colds. I know when it is warm. So I can just check-in to see if it is running right. I did not really use the app at all because that is just what it is for me". (Participant P13)*

The participant also did not perceive any impact of the sensor intervention on traceability of carcase temperature because it lacked *usefulness and utility* in the context of the relatively *small size of abattoir operations.*

> *"In a different type of business, it would be helpful but in my business. it will not be helpful only because it is a small business and I am in and out of the fridge every day". (Participant P13)*

7.5.2 PERCEIVED IMPACT OF IT ON TRACEABILITY IN THE COLD CHAIN/RETAIL BUTCHER

The sub-theme with the meat processor focused on the technology intervention on *provenance and meat safety*. The core categories are perceived impact on meat safety and perceived impact on meat provenance

7.5.3 PERCEIVED IMPACT OF IT ON TRACEABILITY OF MEAT PROVENANCE AND MEAT SAFETY

The butcher believed that the mobile app intervention raised consumer awareness regarding the possibility of gaining access to more information about the lamb.

> *"I think it is good. It is traceability. Definitely, a couple of people were asking about it. I think it gets people attention going. It is good to let people know that we care". (Participant P16)*

In terms of meat safety, the participant was indifferent concerning the impact of the technology intervention on the cold chain.

> *"Yeah, if we have an abattoir it would not be a bad idea" (Participant P16)*

7.6 SUMMARY OF SUPPLY CHAIN MAPPING, BASELINE DATA COLLECTION, TECHNOLOGY INTERVENTION, AND POST-INTERVENTION FOR CASE STUDY 3

This section presents a summary of the findings from case study 3. A total of three participants were involved in this case study comprising of a farmer/road transport, meat processor, and cold chain/retail butcher. The research explores traceability challenges amongst small businesses along the lamb supply chain. At the level of operations, there were marked differences in traceability practices, organisational priority and perceived traceability challenges. At the level of technologies, IT use and adoption amongst the small businesses were different. The meat processor and retail butcher utilised some form of IT in their businesses to support traceability, while the utilised IT minimally in the farm for accounting purposes. At the level of information, data requirements include (a) NVD information, RFID in the farm; (b) tattoo ink label on the lamb carcase in the abattoir; (b) display case label on meat cuts in the retail store.

After the supply chain mapping exercise emerged that only the retail butcher perceived some form challenges with the product traceability of lamb along the chain, specifically with accessibility to information on meat provenance and opportunities to apply that information for marketing. In the cold chain, the butcher did not perceive any challenges but was interested in exploring traceability opportunities. The farmer did not perceive any challenges with existing traceability practices, and as a result, was did not progress further in the study. The meat processor did not perceive any challenge with current traceability practices but was interested in exploring new technology experiments (Phase 2) and also to provide feedback in the post-intervention evaluation phase (Phase 3). Based on this feedback, the research selected the retail butcher for baseline data collection to support visibility assessment in the chain.

Baseline assessment of visibility collected from the retail butcher indicated a perceived average level of visibility to issues of meat provenance and meat safety.In responding to some of the critical traceability challenges faced by the butcher in the chain, as well as provide opportunities for technology utilisation in the meat processor, the research proposed and deployed four low-cost mobile technologies in the case study. These technologies were deployed within the processor, cold chain and retail segment of the lamb supply chain. In the meat processor, technologies deployed include barcode labelling systems, and a Bluetooth wireless temperature monitoring system. Along the cold logistics chain, the research deployed a portable Blulog® temperature traceability system to enhance visibility to meat temperature information. In the retail butcher phase, a QR code enabled mobile meat verification app deployed over a web app backend traceability was implemented in the store. The technology intervention revealed the temperature performance of the abattoir and cold chain and indicated the timing of operations that are exposed to potential risks of temperature abuse in the chain.

In the post-intervention and evaluation phase, the retail butcher and meat processor exhibited marked differences in their perceptions concerning the role and potential impact of the mobile technology intervention on traceability and organisational operations along the lamb chain. In the meat processor, the key findings were as follows:

- Meat provenance: The meat processor perceived a new role of the labelling system on traceability to enhance identity preservation and provenance of lamb, but did not perceive any significant impact on traceability within the abattoir operations. The participant also believed that the labelling system did not align with the existing business focus, organisational objective and priority of the processing plant.
- Meat safety: The meat processor did not perceive any new role or potential impact of the sensor intervention on traceability of meat temperature information in the abattoir. The participant believed that sensor intervention was not important to the businesses and did not provide any significant improvement in information quality and traceability.

In the retail butcher, the key findings are as follows:

- Cold chain: The participant perceived a new role of the portable temperature sensor intervention in the cold chain but did not perceive any significant impact on traceability in the cold chain operations. The key issue was the perceived difficulty involved with co-ordinating the participation of the meat processor to support continuity in visibility and traceability of the lamb along the chain. In this context, the participant appeared to perceive neither a positive or a negative impact of the intervention on the cold chain.
- Meat provenance: The retail butcher perceived a new role of the mobile technology intervention on traceability in a number f areas, including the enhanced capacity for verification of meat origin, enhanced consumer awareness and consumer assurance in the retail butcher store.

Chapter 8

Analysis of Findings: Case study 4

8.1 INTRODUCTION

This chapter presents the findings that emerged from the analysis of field data for case study 4, a local retail butcher aligned to the major beef meat supply chain in Tasmania. The presentation is organised in 3 parts, and these are pre-intervention (supply chain mapping and baseline data collection), technology intervention and post-intervention and evaluation. The breakdown of the section of the analysis chapter is as follows. **Section 8.2** presents the overview of the key findings that emerged from case study 4. **Section 8.3** presents the analysis of key findings that emerged from Phase 1-pre-intervention (step 2-supply chain mapping and step 3-baseline data collection). **Section 8.4** presents the analysis of key findings that emerged from Phase 2-technology intervention. The key findings from **Phase 1 and Phase 2** will provide answers to **Research Question 1**: *How can low-cost mobile technologies be utilised and deployed amongst small businesses in red meat supply chains to support traceability, and for responding to challenges faced?* **Section 8.5** presents the analysis of findings for phase 3 post-intervention phase. The key findings from **Phase 3** will provide answers to **research question 2**: (a)*What criteria do small businesses in red meat supply chains use in evaluating the role and potential impact of low-cost mobile technologies in supporting traceability, and for responding to challenges faced*?; (b) and **research questions 3**: How *can a small business traceability framework be developed to support the implementation and evaluation of low-cost mobile technologies to support traceability and for responding to challenges faced?* **Section 8.6** summarises the key findings from the chapter.

8.2 OVERVIEW OF KEY FINDINGS FROM CASE STUDY 4

Case 4 is a local retail butcher store operating in the lower sandy bay area, Hobart, Tasmania. The research invited all key businesses involved in the beef supply chain linked to the retail butcher, and these include farmer, cattle transport, meat processor, cold chain, and the retail butcher. All invited participants except the retail butcher 3 (participant P18) declined participation in all phases of the study, i.e. Phase 1-step 2(supply chain mapping), and step 3 (baseline data collection). As a result, this case study explores traceability challenges impacting the retail butcher store and aims to understand the role and potential impact of low-cost mobile technology.

The butcher shop sells a range of meat products including lamb, chicken, beef, pork, fish, small good. There are also value-added products and condiments produced in-house to supplement the meat range such as marinated meats. The retail butcher is partially aligned to two primary meat processors in Tasmania that supply meat products to the shop. The research interviewed the owner-manager (P18) of the retail store to map internal and external organisational traceability practices in the beef supply chain. The map of the internal traceability practice of the retail butcher is found in the appendices (Appendix F). The key findings that emerged from case study 4 are as follow.

1) In Phase 1 (Step 2-supply chain mapping), the **retail** did not perceive any challenge with existing traceability practices both within the store and along the supply chain concerning issues of meat provenance, meat safety, meat quality, and animal welfare. However, despite this inability to see challenges, the participant was open to exploring opportunities for improvement in visibility in areas of meat safety (temperature monitoring) and meat provenance (verification of meat origin).**In the baseline data collection step**, the participant perceived a higher level of visibility to potential traceability challenges related to issues of meat provenance and meat safety.
2) **In Phase 2(technology intervention),** the research deployed two low-cost mobile technologies within the butcher store to enhance the visibility in two key areas namely meat safety (temperature monitoring) and meat provenance (proof of origin).
3) **In Phase 3, the post-intervention and evaluation,** the participant perceive a positive role and impact of the mobile technology intervention on traceability in the area of meat safety within the store, and but no significant role or impact of mobile technology in the area of meat provenance. In terms of meat safety, the technology intervention impacted positively on information quality and organisational operations In evaluating the impact of the technology intervention on traceability, the participant considered two main criteria that could impact positively or negatively on the useability and

potential adoption of new technologies in the store and these are consumer interest and technology portability.

The next section below presents a detailed analysis of the key findings from Case study 4.

8.3 PHASE 1: SUPPLY CHAIN MAPPING STEP

8.3.1 OPERATIONS

At the level of operations, the participant (P18) performs three main activities, and these include *ordering of new stocks, receiving of new stocks, display and retail*. In the ordering phase, the butcher places new stock branded boxed meat products as purchased directly from a meat processor. The butcher does not participate in whole carcase supply chains, and as a result, does not require a stock agent nor engage with the saleyard or farmers directly. All meat orders are processed directly through the processor who performs a range of pre-slaughter activities, including procurement of livestock, processing, and branding. These activities are similar for both lambs and beef supply chains. For example, in the lamb supply chain, the participant mentioned the following:

> *"They buy the lambs there and kill them, and then we just put our order in". (Participant P18)*

The butcher also mentions the following regarding beef supply chain:

> *"Basically we just order boxed beef off them. They have got it all the time. They are one of the world's biggest producers". (Participant P18)*

The butcher mentioned the difficulty in sourcing Tasmanian grown meat products. In his opinion, this is because most local farmers prefer to sell for higher prices to the mainland and to export markets rather than sell to local butchers. This preference for higher price premium means that butchers have to rely on multiple sources of branded meat processors to fulfil consumer demands, and this could be from Tasmania or other parts of Australia.

> *"No, look, there are stages where you cannot get everything Tasmanian because a lot of mainland Australia buys a lot of Tasmania stuff, so they understand If you cannot get it, they will buy the other stuff. But which we try, we try to get the majority of Tasmania stuff anyway". (Participant P18)*

Once meat orders are processed through the abattoir, it is despatched through a third-party logistics provider who then delivers it to the store. The shipment is accompanied by a waybill(Appendix X) from the transport operator. At the delivery point, the product is loaded into the cold room.

Further secondary processing includes dis-aggregating each boxed meat into traditional meat cuts. Each meat cuts is labelled with a ticket which displays the name of the product and product code (Appendix W). The customers view different cuts displayed in the chilling cabinet and make purchasing decisions based on their references.

> *"Yeah. Yeah, they [consumers] just come in, we have got the, basically our tickets in them, that say what kind of meat it is. That is it. You know what I mean, they know what they want to do with it and that sort of stuff. So yeah". (Participant P18)*

8.3.2 TECHNOLOGIES

At the level of technologies, the main IT tools utilised in the store include a laptop computer, wireless internet, email, and a mobile phone. The laptop is used for sending and receiving emails, and these include invoices, placing new orders with the processor or for making general inquiries about new product brands available for purchase. Wireless internet enables internet access from mobile and laptop computer. However, the butcher stated that amongst the technologies identified in the store, the most important is the mobile phone.

> *"Keep it to a bare minimum. Not in my specific business because all communication is done by phone with our orders and if we had every single one of our orders, it is done by my phone, none of them by email or anything like that". (Participant P18).*

8.3.3 INFORMATION

The key information aligned to beef include and these *shipment waybills, carton labels, and invoices*. The invoices carry information about the specification of meat orders that were processed by the meat processor. Important data elements include price, the number of boxed meat orders, data of processing, name and address of processor, and delivery address. The waybill is a shipment declaration document generated by the logistics operator describing the type of shipment, date of pickup, name of driver, sender, name of receiver and date of delivery. The waybill also contains a spot temperature information that indicates the micro-environmental condition of the truck as at the time of delivery of the shipment in the store. The carton labels are standard labels generated by the meat processor which provide essential data elements to ascertain provenance and quality of the meat back to the meat processor. The key data elements related to meat provenance include name, address and location of the meat processor. The data elements aligned to meat quality include brand program name, type of meat products, weight, MSA grade of the beef, feed input (grass or grain-fed), dentition, sex of the animal, and age. The participant stated that these data elements it is possible to ascertain the traceability of meat in terms of its geographical origin.

> *"Like in some brands of beef, we can tell that it is Victorian or Tasmanian, you know". ". (Participant P18)*

8.3.4 POTENTIAL TRACEABILITY CHALLENGES

The interview in this section focused on understanding the potential traceability challenges impacting the retail butcher operations in the supply chain and the current role of IT. The core categories that emerged from this analysis relate to issues of meat provenance to meat *provenance*, *meat safety*, *meat quality*, *and animal welfare*. The key findings that emerged from these core categories are presented in the next section.

8.3.4.1 MEAT PROVENANCE

One sub-category emerged concerning the participant's perceived potential traceability challenges related to meat provenance, namely **access to product traceability information**

8.3.4.1.1 ACCESS TO PRODUCT TRACEABILITY INFORMATION

The participant did not perceive any challenge with ascertaining the provenance of the beef meat because the information can be verified from the label or directly by contacting the meat processor.

> *"I will just ask, um, well, you can tell by specific brands they have specific brands, you know what I mean in cartons and all that sort of stuff. And I will generally if they come up with a new one I will say, well where is that from? You know what I mean? And is it grass or grain or whatever".(Participant P18)*

The participant then stated the following.

> *"For origin is still pretty close to quality. You know what I mean? Just in case they do want to know where it's from. We have to know where it's from". (Participant P18)*

8.3.4.2 MEAT QUALITY AND AUTHENTICITY

One sub-category emerged from participant's perceived potential traceability challenges related to meat quality and authenticity, namely ***transparency and supply chain trust.***

8.3.4.2.1 TRANSPARENCY AND SUPPLY CHAIN TRUST

The participant stated that the quality of beef could be traced to the brand and the critical information linked to meat quality relate to the type of animal feed used to grow the livestock, *i.e. grass or grain-fed.*

> *"No. we have got specific cuts that specific sort of brands that are grass-fed. So yeah, yeah, like your cape grim beef that sort of stuff". (Participant P18)*

However, the participant also stated that his customers seldom ask for additional information on meat quality in the butcher store because of the *level of trust and relationship* that has been built over time.

> *"I will be honest, I don't get a lot of people asking what it is, you know what I mean? So yeah, yeah, that's something like you build up trust with them and you're basically once you've got their trust it's fine, but we do get a few asking for grass, you know what I mean? But the majority of our [meat] is grass anyway so yeah" (Participant P18)*

8.3.4.3 ANIMAL WELFARE AND MEAT SAFETY

Two sub-categories emerged from participant's perceived potential traceability challenges concerning issues of animal welfare and meat safety, and these are ***supply chain trust and compliance**, **and accessibility to meat safety information*****.**

8.3.4.3.1 SUPPLY CHAIN TRUST AND COMPLIANCE

In terms of animal welfare, the participant does not perceive any traceability challenge with animal welfare because he *trusts* that the suppliers are complying with requirements on proper handling and care of animals in the supply chain

> *"You know what I mean? As I said, there would not be, they would not be supplying it towards if it was not if the welfare of the animals was not done properly. So you trust them more with 100 per cent in Australian they have to do it like that".(Participant P18)*

In the cold logistic chain, the participant did not perceive a challenge in the ability to ascertain the temperature condition in which the meat product has been transported along the cold chain because of trust between his business and the transport operator.

> *"Um, well it is the same old story there. they are a global chain, and they are going to have everything. So we trust them, they are gonna have everything, you know, the process is going to be correct. Otherwise, they would not be operating you know what I mean" (Participant 16)*

The participant also added the following:

> *"Because they check the temperature when it arrives in our store. They have got a log. They have got a log on their transport documents in which to sign, and they'll put what temperature it was when it arrived because they have got the um, they have got the temperature in their truck, like a little digital one and they will just look at that and say four degrees and yeah". (Participant P16)*

8.3.4.3.2 ACCESSIBILITY TO MEAT SAFETY INFORMATION

In terms of meat safety, the butcher did not perceive any challenge with the ability to monitor and ascertain the temperature condition of the beef products in the supply chain. **In the processing phase**, the participant stated that the critical information of importance is the shelf life, and that information can be accessed by contacting the supplier directly.

> *"Oh, we just like everything is got to a use-by on it, the, the boxed beef, you know, you know, that has got about six to eight weeks, the shelf life on it. So if it starts to push towards the six or seven weeks, you sort of do not get it in. I always ask my supplier, and each shop got Different people they talked to every day. So I will just say to aBCX at company AB - What, do you know, what term date range is on it?" (Participant P18)*

In the butcher store, the participant stated that he does not perceive any challenge with his ability to monitor the meat temperature in the cold store because information can be assessed through the digital temperature gauges

> *"I just saw the temperature rising on the fridge and the digital gauges in it, you know what I mean, and so I just ring ABCX up, and he comes right down" ".(Participant P16)*

8.3.4.4 FEEDBACK FROM CASE STUDY PARTICIPANT AFTER SUPPLY CHAIN MAPPING EXERCISE

As mentioned in Section 8.2, only the retail butcher participated in the supply chain mapping exercise. Following the exercise, the retail butcher was contacted to discuss and prioritise some of the potential traceability challenges being faced in the enterprise. The aim was to obtain feedback from the participant concerning the perceived criticality of the traceability challenges faced and the willingness to progress to the next step (i.e. baseline data collection), Phase 2 (technology intervention), and Phase 3 (post-intervention). It emerged from the meeting that the retail butcher did not perceive any traceability challenges with regards to issues of meat provenance, meat safety, meat quality, and animal welfare. However, he was willing to progress further to complete the entire phase of the study and to explore visibility improvement opportunities in areas of meat safety (temperature monitoring in the refrigerator) and meat provenance (geographical traceability/proof of origin). Thus, baseline data collection focused on these key areas. The details of the analysis are presented in the next section below.

8.3.5 STEP 2: BASELINE DATA COLLECTION

Baseline data collection was obtained from the retail butcher (Participant P18) to assess the perceived level of visibility to potential traceability challenges in meat provenance (geographical information), and meat safety (temperature information). Table 17 below shows the butcher's assessment of the current level of visibility to temperature in the store in terms of accessibility, accuracy and freshness and currency. In term of accessibility, the participant believed that he had between 50-75% information on the temperature condition of the refrigerating equipment in the store. This assessment is based on the premise that information generated by visual observation and body temperature assessment constitute 50-75% accessibility to temperature information. In terms of accuracy, the butcher believed that accuracy of information obtained from the analogue sensors is satisfactory. The participant provided this judgement based on his belief in the accuracy of the analogue and digital sensors of the chilling equipment (See Appendix X). In terms of freshness and currency, the participant believed that the current level of information could only be updated when in-store. This judgement is based on the physical observation in the store. Based on this visibility assessment, a total visibility score of 3.3 was obtained, indicating that the participant believed he possessed high-level visibility to temperature information within the cold storage area of the butcher store.

Table 17: Butcher’s perceived level of visibility to traceability challenges of meat safety (Butcher node- temperature information in the retail butcher store

Prioritised traceability challenge (butcher node)	*I have access to a fairly good amount (50-75%) of the information*	*The accuracy of exchanged information is always satisfactory*	*information is updated only when I ask suppliers to provide data*	*Node visibility*
	Accessibility	Accuracy	Freshness and currency	Visibility score
Meat safety	3	4	3	3.30

Table 18 below shows the visibility assessment of the retail butcher concerning the provenance of beef purchased from the processor node. In terms of accessibility, the butcher scores himself 4, indicating that he has more than 75% of the information needed to ascertain the provenance of the beef products in the supply chain. In terms of accuracy, the butcher scores himself 4, indicating that the information provided by the processor is always satisfactory. In terms of freshness and currency, the participant scored himself 1, indicating that the speed with which information is retrieved from the carton or the processor is not always satisfactory. This means that the participant either needs to contact the supplier regarding information in the meat product or that the customer needs to wait at the counter for the information to be retrieved from the cold store where the cartons are stored. Based on this assessment, total visibility calculated for meat provenance is 2.52, indicating that the retail butcher perceived a high level of visibility to origin of beef (See Chapter 3, Section 3.6.3.1, Table 9).

Table 18: Butcher’s perceived level of visibility to traceability challenges related to meat provenance.

Prioritised traceability challenge (processor node)	*I have access to a large part(more than 75%) of the information*	*The accuracy of exchanged information is always satisfactory*	*information is not always updated and not always satisfactory*	*Node visibility*
	Accessibility	Accuracy	Freshness and currency	Visibility score
Meat provenance	4	4	1	2.52

8.4 PHASE 2: TECHNOLOGY INTERVENTION

Following the baseline data collection step, the research held a consultative meeting with the retail butcher to discuss low-cost mobile technology options that can be deployed in the store and enhance visibility and product traceability in areas of meat safety and meat provenance. Based on the feedback received, two mobile technology interventions were implemented, and they include a wireless temperature sensor network and a mobile meat verification app. The discussion of each intervention is presented in the next section below.

8.4.1 WIRELESS TEMPERATURE SENSOR NETWORK INTERVENTION

The research implemented a SensorPush® Bluetooth®wireless temperature sensor network in the butcher store to enhance the amount and quality of temperature information available in the store refrigerating that can be enhanced further in areas of accessibility accuracy and freshness and currency. The technology architecture consists of a SensorPush® WiFi Gateway, two portable temperature sensor tag, a mobile application installed on an iOS device and an internet gateway. The intervention took place between July to October 2018. This date was arranged based on mutual agreement between the researcher and the retail butcher. One wireless sensor was installed in the cold room, and another sensor was installed in the display cabinet area within the store (See Appendix X).

8.4.2 MOBILE MEAT PROVENANCE SYSTEM INTERVENTION

Figure 31 shows the user interface designed specifically for the butcher and the web application utilised for presenting the provenance information to the consumers. Similar to other cases, the research followed the same implementation protocol as described in Chapter 3 (See section 3.4.2). The technology intervention was carried out for a bone beef product whose provenance was limited to the processor. The boxed belong to a beef cattle that were slaughtered on the 14th September 2018 and despatched on the 17th of September,2018. As shown in Figure 31 below, the key data elements utilised for implementing the provenance system include meat type, barcode number, farm origin (indicating processor traceability), name of the processor, cold transport and date of pick up and delivery, and retail. In terms of meat quality, four data elements were captured, including feed type, carcase weight, MSA grade (GRL=Grill), and certification (Halal certification). This experiment was conducted for one month between Oct 1-Oct 30th,2018.

A B

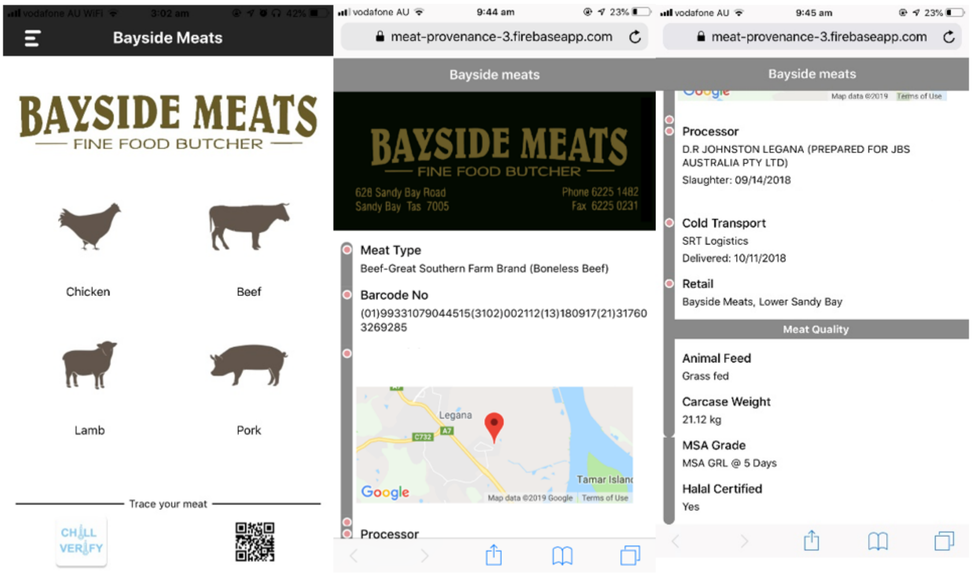

Figure 31: A mobile meat provenance system implemented in the retail butcher store: (a) consumer verification app; and (b) provenance verification for the beef product utilised in the study

8.4.3 ANALYSIS OF FINDINGS

8.4.3.1 TEMPERATURE SENSOR MONITORING SYSTEM

Figure 32 below shows the temperature profile for the display cabinet and cold room, respectively. The average temperature for the display cabinet is 5.3°C with the highest temperature of 20.5°C and lowest temperature of 1.2°C. In the cold room, the temperature condition is relatively stable at an average of 3.7°C. The temperature range of -0.3°C to 19.3°C is observed during the period. The display cabinet experience more than 15 spikes in temperature above the maximum threshold of 5°C during the intervention period between August -Septemeber. The butcher mentioned that the spikes occurred when the cabinet was non-operational.

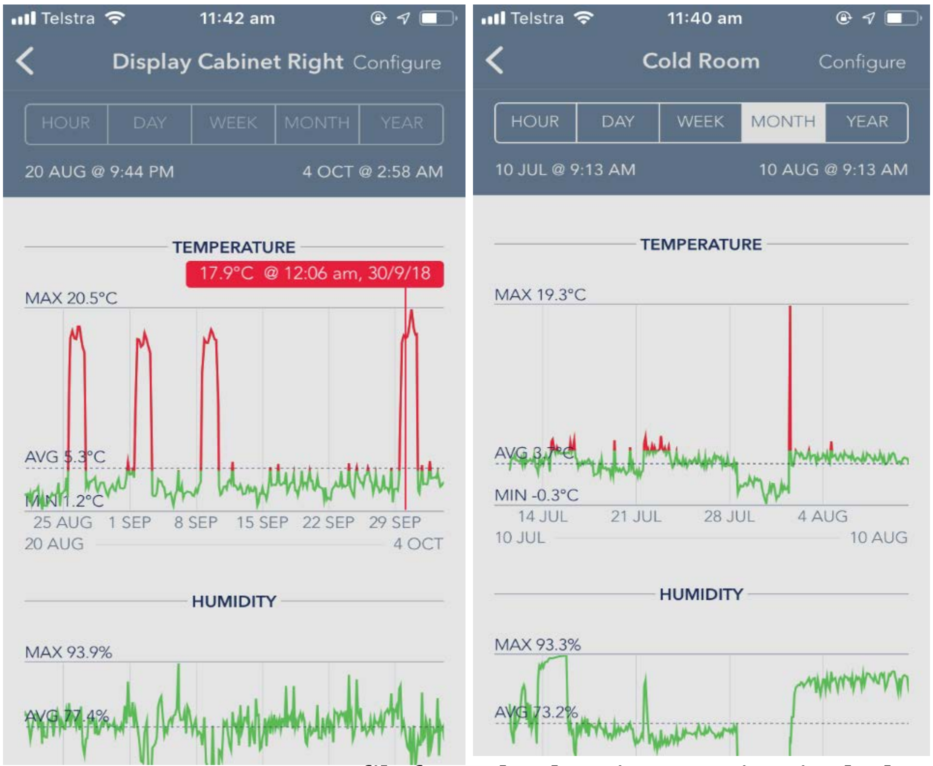

Figure 32: Temperature profile for technology intervention in the butcher store: Left- display cabinet temperature profile, and Right- cold room temperature profile

In the cold room, temperature chart shows a significant number of spikes above the maximum threshold of 5°C. The cold room sensors also captured temperature condition at freezing temperature indicating the instability of refrigerating equipment performance at certain times of the month. The participant suggested it was not uncommon to find abrupt temperature spikes in the store because the doors of the cabinet and in the cold room may have been left open for more extended periods during daily operations and the sensors may have captured slight changes in the micro-environmental conditions.

8.4.3.1.1 Mobile Meat Provenance System

The statistical chart obtained from the Android and iOS store can be found in the appendices (Appendix Y). It shows that no consumer app download the app; neither was there any interaction with the QR code to verify the provenance of the beef selected for the traceability implementation.

8.5 PHASE 3: POST-INTERVENTION EVALUATION

In the post-intervention, the retail butcher was contacted to provide his feedback regarding the potential impact of the sensor intervention in the traceability of temperature in the store. The interview focused on two key themes aligned with the intervention and they are *perceived technology impact on meat safety (temperature traceability) and perceived technology impact on meat provenance (meat verification)*. The core categories that emerged under each theme are presented in the next section below.

8.5.1 PERCEIVED IMPACT OF IT ON MEAT SAFETY (TEMPERATURE TRACEABILITY)

This theme describes the participant's response regarding the impact of sensor technology intervention on temperature traceability in the butcher store. The core categories are perceived impact on visibility and information quality, perceived impact on organisational practices, technology evaluation criteria.

8.5.1.1 PERCEIVED IMPACT ON VISIBILITY AND INFORMATION QUALITY

The participant perceived that the sensor technology intervention improved visibility *in monitoring the* temperature condition of the refrigerating equipment in the store.

> *"We could not actually monitor it like we did until you put the monitors in. But yeah very good".(Participant P16)*

The participant also believed that the sensor technology intervention enhanced the quality of information related to meat temperature information in the cold store.

> *"Just to monitor things and have all the plots and that sort of thing. Yeah".(Participant P16)*

The participant also added the following

> *"Yeah, definitely. Yeah, definitely I can monitor what is actually happening a lot closer than what we can if we have not got them in there".(Participant P16)*

The participant perceived that technology intervention enhanced the ***reliability of temperature information*** that is utilised to monitor the refrigerating equipment through the mobile phone

> *"Just the consistency of it. Okay, very good. It is good to be able to keep track of how it is going and that sort of thing". (Participant P16)*

8.5.1.2 PERCIEVED IMPACT ON ORGANISATIONAL PRACTICES

The participant also perceived that the sensor technology intervention could play a positive role in enhancing *organisational responsiveness to meat safety risks*.

> *"It helps in the case of an emergency. You know what I mean? It will go off, and I will come down and rectify things. You know what I mean like it can always come through to me and let me know and that fine".(Participant P16).*

8.5.1.2.1 TECHNOLOGY EVALUATION CRITERIA

The participant perceived that sensor intervention was portable and easy to use. In terms of the *portability of the sensor intervention*, the participant stated the following.

> *"You know like monitor it on your phone when you are at home or anything like that".(Participant P16)*

The participant also added the following:

> *"It is very handy to be able to keep track of everything while you are not at work that sort of thing if you are away or anything like that. Yeah. Very good".(Participant P16)*

8.5.1.3 PERCEIVED TECHNOLOGY IMPACT ON MEAT PROVENANCE

The participant did not perceive any impact of the mobile app intervention on meat provenance because of *lack of consumer interest*

> *"It is a good idea but like you have to pick the best areas [location] to put it. Like mine customers are more interested in coming in, getting their product and going. That is it. That is what happens". (Participant P16).*

The participant also stated that most of the consumer's visiting the store prefer to ask the butcher directly for more information concerning the beef rather than scan the QR code with their mobile devices.

> *"I think that people would rather ask the butcher direct, you know, if they specifically want to know anything about that meat, where it is from or anything like that they prefer to ask us straight out rather than sort of getting the phone out, going to the app. Because you know everybody is fairly busy and if they take the time with that that they can ask us within two seconds while we are serving them. You know what I mean. How it's brought up and that sort of stuff they*

> *just ask us. We can give the answer in two seconds". (Participant P16).*

8.5.2 SUMMARY OF SUPPLY CHAIN MAPPING EXERCISE, BASELINE DATA COLLECTION, TECHNOLOGY INTERVENTION AND POST-INTERVENTION EVALUATION FOR CASE STUDY 4

The section presents a summary of the key findings from the case study 4. The research explored potential traceability challenges impacting the retail butcher store. At the level of operations, the participant's key focus on traceability included ascertaining meat provenance, meat safety, meat quality and animal welfare. However, these were not considered important issues to the businesses because the information could be obtained if needed, and due to the perception that most of the customers visiting the store dod not bother about traceability when purchasing beef products in the store. In this context, the participant did not perceive any challenge with regards to internal and external traceability of beef in the areas of meat provenance, meat safety and animal welfare and meat quality/authenticity.

At the level of technologies, the research found that IT use within the store is limited in the role played in traceability and in supporting butcher operations. The participant preferred limited IT use in the store due to the lack of interest. At the level of information, the participant believed he had access to all information required to support internal and external traceability, and this can be achieved by communicating directly with the suppliers through the mobile phone or by extract important information from the carton labels. In terms of meat safety, the participant believed that body temperature assessment could be used to ascertain the performance and temperature condition of the fridge. Traceability related to meat quality, it was gathered, can be assessed through the carton label assigned to meat cut. Key information includes grass-fed and grain-fed beef. In terms of animal welfare, the participant believed that the supplier reputation in the red meat industry would suggest that they adequately handle and care for the animals sold to consumers. In the context of existing beliefs surrounding the butcher store traceability practices, the participant stated that he did not perceive any challenge with traceability across meat provenance, meat safety, meat quality, and animal welfare. However, the participant was open to exploring opportunities for improvement in meat safety (temperature monitoring) and meat provenance (verification of meat origin).In the baseline data collection step, the participant perceived a higher level of visibility to the traceability challenges in both areas of meat provenance and meat safety.

Baseline data collection in areas of meat provenance and meat safety showed that the butcher perceived his level of visibility to potential traceability chains to be high, indicating the string belief in existing practices. **In the technology intervention phase,** the research deployed two low-cost mobile technologies to enhance the amount and quality of information that is currently available in the store in both areas of meat safety and meat provenance and can be captured to support enhanced visibility in information on meat provenance and meat safety in the. The technologies played new roles in the areas of meat safety (temperature monitoring) and meat provenance (verification of meat origin).

In the post-intervention and evaluation, the feedback received from the participant showed that the technology intervention played a new role in traceability for meat safety but did not play any significant role in meat provenance. In evaluating the impact of the technology intervention on traceability, the key findings were that:

- **Meat safety:** The sensor technology intervention played a new role in positively impacting traceability (temperature monitoring and visibility improvement) and organisational responsiveness to risks of temperature abuse in the store.
- **Meat provenance:** The mobile verification app did not play any new role in the verification of meat origin due to no consumer interaction and lack of consumer interest in product traceability.

Chapter 9

Cross-Case Analysis of Findings

9.1 INTRODUCTION

This chapter presents the cross-case analysis of the key findings generated from the multiple case studies presented in analysis chapters (Chapter 4-8). This sections in this chapter are divided as follows. Section 9.2 presents the overview of key findings that emerged amongst the case studies. Section 9.3, the research provides a summary of the cross-case analysis and elaborates on how the findings provide important answers that address the research questions.

9.2 CROSS-CASE ANALYSIS

This section presents a cross-case analysis of the four case studies that were explored in this study. Table 19 below shows the key findings that emerged from the analysis of case studies within this exploratory research. The table consists of 5 columns summarising the key findings generated from the case studies. The first column highlights the number of case studies involved in the exploratory and the supply chain segment in which they operate. In total, 4 case studies were explored in the study covering different parts of the red meat (beef and lamb) supply chain.

The second column highlights the number of key participants involved in each case study segment and these are: case study 1 (cattle farmer-transport-saleyard); case study 2 (stock agent-wholesale-retail butcher); case study 3 (Lamb Farmer/transport, meat processor, cold chain/retail butcher); and case study 4 (Retail butcher).The case studies were selected and organised into segments based on approach to traceability utilised by the small businesses, in what can be described as OUOD traceability.

The third column shows the potential traceability challenges that the small businesses and focal participants perceived to the most significant in each segment. Four traceability challenges were identified by the participants, and these relates to issues issues of animal welfare, meat safety, meat provenance and meat quality/authenticity. In the area of animal welfare, traceability challenges were found to be aligned to issues of monitoring animal behaviour and oestrus detection. In the area of meat safety, key issues related to the inability to monitoring meat temperature in the processing, cold chain and retail phase of the red meat supply chain. In the area of meat provenance, traceability challenges were found to linked to issue of verification of meat origin. In the area of meat quality, potential

Table 19: Cross-case analysis of key findings on traceability challenges amongst small businesses and the role and potential impact of low-cost mobile technologies

Case study	Small businesses	Potential traceability challenges	Focal firm(s)	Research Question 1 (New Role of IT)	Baseline assessment	Perceived impact	Research Question 2 (Criteria for technology evaluation)
Case study 1	Farmer/cattle transport and saleyard	Animal welfare	Farmer	Behavioural monitoring	Animal welfare= 3	Negative	Information quality (usefulness, currency, freshness); organisational (perceived commercial benefit, value proposition)
Case study 2	Stock agent, wholesale, and retail butcher	Meat provenance, authenticity, and meat safety	Retail butcher	Proof of origin/meat verification, temperature monitoring	Meat safety=2.62	Positive	Information quality (accessibility, completeness, freshness); organisational awareness, visibility of operations, changes in staff behaviour, improved decision making
					Meat provenance=2.88		consumer awareness, product marketing,
Case study 3	Lamb Farmer/transport, meat processor, cold chain/retail butcher	Meat safety, meat provenance	Meat processor	Temperature monitoring	Did not participate	None	Perceived usefulness, size of business operations
				Carcase labelling	Did not participate	None	Carcase identification, perceived lack of suitability
			Retail butcher	Cold chain monitoring	Meat safety=2.08	None	Information quality (accessibility)
				Proof of origin/Meat verification	Provenance=1.83	Positive	Consumer awareness
Case study 4	Retail butcher	Meat safety and meat provenance	Retail butcher	Temperature monitoring	Meat safety=3.30	Positive	Visibility of operations, information quality (accessibility, currency and freshness, reliability), organisational responsiveness to risks,
				Meat verification/proof of origin	Meat provenance=2.52	None	Consumer interest

traceability challenges were linked to the inability to support product marketing and consumer responsiveness and verification of meat products in the store.

The fourth column highlights the supply chain actor(s) that were perceived to be most impacted by the traceability challenges identified in each segment. The most impacted in this study include the farmer, meat processor, cold chain logistics and the retail butcher. The fifth column highlights the new role of IT in traceability for responding to the challenges faced in each case study. This column also provides important insights for answering the relevant research question underpinning this study. In the first research question, the study aimed to understand: *1) How can low-cost mobile technologies be utilised and deployed amongst small businesses in red meat supply chains to support traceability, and for responding to challenges faced?* In the area of animal welfare, low-costs mobile sensor devices were deployed in the farm and on the animal and utilised to support continuous monitoring of changes in animal behaviour as a proxy for detecting potential illness and oestrus. In the area of meat safety, low-cost mobile sensor devices were deployed in the abattoir, cold chain, and retail butcher segment, and utilised to support continuous monitoring of changes in meat temperature and to respond to issues of temperature abuse and meat spoilage. In the area of meat provenance and meat authenticity, the research deployed low-cost mobile applications and web applications using QR codes and customer mobile devices to support verification of meat origin. This technology also provided support for authentication of meat, support consumer awareness and opportunities for product marketing in the retail phase of the chain amongst the case studies.

The sixth column shows how the focal participants involved in each case study perceived their level of visibility based on the heuristic framework proposed and utilised in the field. The small businesses that participated in this baseline assessment perceived their level of visibility to potential traceability challenges to be moderate to high along different parts of the chain in areas of animal welfare, meat safety, meat provenance, and animal welfare. This column also provides important insights for answering the second research question underpinning this study: *What criteria do small businesses in red meat supply chains use in evaluating the role and potential impact of low-cost mobile technologies in supporting traceability, and for responding to challenges faced*?

The seventh column shows the perceived impact of IT in traceability. This column provides important insights for answering the third research question; How *can a small business traceability framework be developed to support the implementation and evaluation of low-cost mobile technologies to support traceability, and for responding to challenges faced?* This will be discussed in more detail in Chapter 10: As seen in Table 19 above, there were markedly different perceptions amongst small businesses concerning the potential impact of IT on traceability. While some participants perceived some positive impact of IT on traceability, there were others that did not perceive any impact or had a negative of IT on traceability. As seen in Table 19 above, the analysis of findings from the multiple case studies revealed several new key findings that provide answers to the research questions underpinning this study Firstly, in **the pre-intervention (supply chain mapping** step), the research revealed multiple traceability challenges between the case studies and these were related to key issues of meat provenance, meat safety, meat quality and animal welfare. Amongst the case studies, the traceability challenges were similar between some cases, e.g. between case study 2, case study 3, and case study 4 in terms of issues meat provenance, meat safety, and meat quality.

However, there were also unique traceability challenges, such as the issues of animal welfare in case study 1. The retail butcher in case studies 2 and 3 did not perceive any significant challenge with traceability practices in the chain particularly in the area of meat safety and animal welfare because of the belief that it was the responsibility of the farmers and meat processors. As a result, he did not prioritise issues of animal welfare as a major traceability challenge. In case study 4, the participant exhibited some level of trust in their suppliers capacity for traceability. Other participants that declined participation relied on their level of accessibility to guarantee the traceability of meat products sold to consumers. Amongst the case studies, the research also found that not all participants that were engaged in the supplied mapping step were interested in progressing further in the study.

For example, in case study 1 (farmer and saleyard operations), while all key participants did not perceive any challenges with existing traceability, only the farmer was interested in pursuing further in the study while the saleyard participant was unwilling to continue in the study. A similar trend is observed in case study 2 (stock agent, wholesale, and retail butcher), where the wholesale and stock agent did not perceive any traceability challenges and thus were unwilling to progress further. Only the retail butcher in case study 2 agreed to continue in the study to pursue areas of improvement by participating in the baseline, technology intervention and post-intervention evaluation. However, in case study 3, amongst the participants interviewed (i.e. lamb farmer, meat processor, and retail butcher), only the retail butcher perceived some challenges with traceability and was willing to progress further in the study to explore improvement opportunities. The meat processor, while he did not perceive any challenges with existing traceability practices, was interested in technology experimentation and post-intervention evaluation. In case study 4, only the retail butcher could be recruited in the study whole other participant declined participation. As a result, only four small businesses operating in different parts of a beef and lamb supply chain were selected to progress to step 3-baseline data collection, phase 2 (technology intervention) and phase 3 (post-intervention evaluation).

In the pre-intervention phase-**baseline data collection step**, most of the focal companies interviewed within the four case studies believed that they had a high level of visibility to some of the critical traceability challenges faced (i.e. animal welfare, meat safety, meat quality, and meat provenance), except for the retail butcher in case study 3 who believed that visibility to meat provenance information was relatively low.

In the technology intervention phase, the research deployed a number of low-cost mobile wireless technologies at different segment of the red meat supply chain to enhance visibility and capacity for traceability for responding to the critical challenges faced. These technologies include mobile wireless temperature sensors, barcode labelling system, cow-activity monitors, and native and web-based mobile application. These technologies were deployed in four case studies: In case study 1, the research deployed a cow-activity monitor to enhance visibility and traceability of animal welfare in the farm. However, intervention faced multiple socio-technical challenges that impacted its useability and applicability in the farm, including issues of poor internet connectivity, animal temperament, farm topography and influence of grazing approach. In case study 2, the research deployed a mobile wireless temperature monitoring system and mobile application to support traceability and provenance within a retail butcher store. A similar technology deployment was replicated in case study 3 and case study 4. Amongst the case studies, the research found that the intervention played similar new roles in traceability in areas of meat provenance, meat safety, and meat quality for case study 2-4, while in case study 1, the IT intervention played a different role in traceability in the area of animal welfare (i.e. animal behavioural monitoring). However, no significant challenges were encountered during deployment in case study 2-4.

In the post-intervention evaluation phase, the focal participants in the four case studies exhibited marked differences in how they perceived the role and potential impact of the technology intervention on traceability and organisational operations. In case study 1 (farmer) and case study 3 (meat processor), both participants did not perceive any significant role and impact of the mobile technology intervention on traceability. In fact, the farmer in case study 1 believed that enhanced visibility in animal welfare could negatively impact business operation over time. Amongst participants in case study 2 -4, some participants believed the intervention impacted positively on traceability and organisational operations in areas of meat provenance and meat safety. However, other participants felt that IT intervention was more significant for meat safety (i.e. temperature monitoring) as compared to meat provenance, particularly in case study 4. In analysing the case studies, the key observation was that while some participants perceived new positive role and impact of the technology intervention on traceability within their firms, others felt a negative and in one case impact of the technology intervention on traceability and organisational operations. The post-intervention evaluation provided mixed responses to the role and potential impact of IT on traceability both within individual firms and along the supply chain.

9.2.1 SYNTHESIS OF FINDINGS ON THE PERCEIVED ROLE AND POTENTIAL IMPACT OF IT ON TRACEABILITY

This section presents a synthesis of findings from the cross-case analysis concerning the perceived role and impact of IT on traceability. The cross-case study showed that individual perceptions concerning the role and potential impact of IT on traceability were markedly different. While some participants perceived new role and positive impact of IT on traceability both within individual firms and along the supply chain, others did not see any significant new role in traceability or impact in operations both within their enterprises and also along the supply chain. For example, in case study 1, the farmer did not perceive any new role or positive impact of the technology intervention on the traceability of animal welfare. In case study 2, the retail butcher perceived the new role of IT in traceability for responding to challenges related to meat safety (temperature monitoring) and meat provenance proof of origin).

In terms of the impact of the technology intervention in the butcher store, the retail butcher in case study 2 perceived new positive impacts in traceability in areas of consumer awareness and product marketing, authenticity, visibility of cold chain operations, and changes in organisational behaviour. In case study 3, the participants involved, i.e. meat processor and cold chain/retail butcher perceived different roles and potential impact of technology intervention on traceability. While the meat processor saw new roles of the mobile technology intervention on traceability in relation to issues of meat safety and meat provenance, he did not perceive any significant impact on existing traceability practices within the abattoir and also along the lamb supply chain. However, this is similar for the cold chain/retail butcher, who mentioned that the mobile intervention on traceability concerning issues of meat provenance might have played new roles on consumer awareness, he indicated that no significant impact was perceived in the chain. However, in the area of meat safety, the retail butcher could not see any new role or impact due to the perceived difficulty in implementing the cold chain monitoring system along the chain resulting from poor digital participants from the meat processor.

In case study 4, the retail butcher perceived new roles in traceability for responding to issues of meat safety, i.e. temperature monitoring but did not see any significant new role in areas of meat provenance due to perceived consumer lack of interest. In terms of the impact the retail butcher in case study, 4 perceived positive impact on IT on traceability in areas of meat safety and no impact on meat provenance.

The participants also provided markedly different criteria used for evaluating the role and potential impact of technology intervention on traceability along the red meat supply chain. For example, in case study 1, the farmer believed that organisational behaviour, information quality, and commercial benefit were useful criteria for evaluating the impact of sensor technology intervention on traceability for animal welfare. In case study 2, the participants mentioned organisational awareness and behaviour, visibility of operation, information quality, consumer awareness and product marketing as useful criteria for evaluating the impact of IT on traceability in areas related to meat provenance and meat safety. In case study 3, the participants involved provided mixed criteria for evaluating the impact of IT on traceability. At the meat processor, the key criteria used to evaluate the impact of IT on meat safety intervention included helpfulness/usefulness, suitability for the business. In the cold chain/retail butcher, the participant utilised a consumer awareness concerning meat provenance intervention and was indifferent concerning the meat safety intervention. In case study 4, the retail butcher utilised multiple criteria such as visibility/monitoring capability and organisational responsiveness (i.e. for meat safety intervention), and consumer interest (i.e. for meat provenance intervention).

9.3 SUMMARY OF FINDINGS

This section presents a summary of key findings from the cross-case analysis. In this chapter, the research explored potential traceability challenges among small businesses along the red meat supply chain in Tasmania. The purpose was to understand what new role and the potential impact can the implementation of low-cost mobile technologies have in traceability within individual firms and along the red meat supply chain. Using the three-phased strategy to guide the conduct of this exploratory study, several new key findings have emerged as follows: **In the pre-intervention-industry familiarisation phase (Step 1)**, the industry stakeholders identified come potential traceability challenges that could negatively impact Tasmanian small businesses in their supply chains. These traceability challenges were linked to issues of *provenance, meat safety, animal welfare, meat quality/authenticity*. In terms of meat provenance, the core categories that emerged include compliance, identity preservation, and Transparency and proof of meat origin. In terms of meat safety, the stakeholders mentioned the issue of *risk of chemical residue detection, risk of heavy metal contamination, and risk of microbial contamination* as potentially impacting Tasmania small businesses along the red meat supply chains. In terms of meat quality, some industry stakeholders cited the issues of substitution and labelling as impacting negatively on some local retail meat butchers in their traceability. In terms of animal welfare, the key issues were found to be related to scheduling and limited visibility in operations concerning handling and care of cattle during road transportation.

In the pre-intervention-supply chain mapping step (Step 2), the research confirmed some of these traceability challenges that were identified in step 1 (industry familiarisation) to be occurring amongst the small businesses in their supply chains at different points. The critical traceability challenges identified include key issues of meat provenance (meat verification/proof of origin, labelling), meat safety (temperature monitoring), Meat quality/authenticity (labelling/meat verification), and animal welfare (behavioural monitoring). **In the pre-intervention-base line data collection (Step 3),** the participants perceived a higher level of visibility and capacity for traceability despite the challenges of poor information quality and limited traceability faced in their supply chain.

In Phase 2(the technology intervention phase), In responding to some of these challenges, the research proposed and deployed some low-cost mobile wireless technologies and sensors to enhance traceability and visibility in information floes related to meat safety, meat provenance, meat quality, and animal welfare. These technologies include (a) cow-activity monitor, (b)portable cold chain tracking solution; (c) temperature sensor networks; (d) mobile application and barcode labelling system. These technologies played new roles in traceability in terms of animal behavioural monitoring, temperature monitoring, carcase labelling and identity preservation, marketing/authenticity, and meat verification/proof of origin. The deployment also showed the feasibility of implementation in the case studies but also highlighted some socio-technical factors that could inhibit their successful utilisation and adoption in the field sites. Amongst the factors identified, geographical terrain, poor internet connectivity, and issues of limited digital participation amongst some actors were found to be the most critical

In the post-intervention evaluation phase, qualitative feedback received from the case study participants in the form of interview responses suggests markedly different views concerning how focal participants perceived the role and potential impact of the technology intervention on traceability. While some participants perceived new roles in traceability and were interested in adopting the system, others held negative views of the intervention and believed the intervention did not fit their business objective and focus. In this context, the research found that the participants' perception of the technology intervention on traceability ranged from positive, negative and in some case, no impact on organisational operations.

The cross-case analysis of findings provides a number of key insights that can help answer the relevant research questions that underpin this study:

- In research question 1, the study aims to answer the following questions: *How can low-cost mobile technologies be utilised and deployed amongst small businesses in red meat supply chains to support traceability amd for responding to challenges faced?* The analysis shows that low-cost mobile technologies can be deployed at critical segments of the red meat supply chain that is most vulnerable to potential traceability challenges and are perceived to be experiencing lower levels of visibility needed for responding to these challenges. In this study, four critical segments were identified along the chain, including farm production phase, meat processor, cold chain logistics and retail butcher. These segments were identified in the pre-slaughter and post-slaughter segment of the red meat supply chain, respectively. A detailed interpretation of these metrics is presented in the interpretation chapter (Chapter 10).
- In research questions 2, the study aims to answer the following question: *What criteria do small businesses in red meat supply chains use in evaluating the role and potential impact of low-cost mobile technologies in supporting traceability and for responding to challenges faced?* The analysis of findings showed that small businesses utilise both qualitative and quantitative metrics for assessing the role and potential impact of IT on traceability. Qualitatively, the participants used information quality metrics aligned to *accessibility, accuracy, and currency and freshness and format*. Qualitatively, the participant's utilised organisational metrics such as responsiveness, organisational behaviour, consumer awareness as important metrics for evaluating the impact of IT on supply chain both within individual companies and also along the supply chain. A detailed interpretation of these metrics is presented in the interpretation chapter (Chapter 10).
- In the research question 3, this study aimed to answer the following question: *How can a small business traceability framework be developed to support the implementation and evaluation of low-cost mobile technologies to support traceability and for responding to challenges faced?* Based on the key findings generated from the application of the heuristics framework, the research can utilise the feedback obtained from participants on the role and potential impact of IT on traceability, to refine and develop a new framework. This new framework will provide new insights concerning how IT can be

utilised and deployed amongst small businesses to support traceability and for responding to some of the critical challenges faced concerning issues of meat provenance, meat safety, meat quality, and animal welfare. The new framework is discussed in detail in chapter 10 (interpretation and discussion of findings).

Chapter 10

Interpretation and discussion of findings

10.1 INTRODUCTION

This chapter presents the interpretation and discussion of the findings generated from the analysis chapters (i.e. chapter 4-8). This section in this chapter is divided as follows. In section 10.2, the research presents a summary of answers to the research questions underpinning this study. Section 10.3 presents a critical reflection on the overall study findings in Phase 1(pre-intervention-industry familiarisation phase). In Section 10.4, the research presents a critical reflection on the overall case study findings. Section 10.5 presents an alternative small business traceability framework for exploring new roles and potential impact of low-cost mobile technologies in traceability amongst small businesses in red meat supply chains. Section 10.6 presents the chapter summary.

10.2 SUMMARY OF ANSWERS TO THE RESEARCH QUESTIONS

This section presents a summary of the answers to the research questions based on the key findings that emerged from the analysis chapters. As stated in the introduction chapter of this thesis, this exploratory study aims to answer 3 key research questions, and these are:

1) ***RQ1***: *How can low-cost mobile technologies be utilised and deployed amongst small businesses in red meat supply chains to support traceability and for responding to challenges faced?*

Low-cost mobile technologies can be utilised to support traceability amongst small businesses, and for responding to challenges at different points along the red meat supply chains in the following areas: farm production phase (animal welfare), meat processor (meat safety and meat provenance), cold chain (meat safety), and retail butcher (meat provenance, meat safety, and meat quality). In the farm production phase, low-cost mobile sensing technologies are utilised to support traceability in area of animal welfare, as follows: monitoring animal movement and ruminating behaviour, the possibility of detecting heat, and in early detection of illness. Different sensing systems have been proposed and utilised to support tracking of changes in the movement of livestock in beef cattle as a way to improve early detection of heat, illness, stress, or abrupt behaviours (González et al. 2008). These include the GEA Cow View system® (GEA Farm Technologies, Bönen, Germany) (Tullo et al.

2016) and OviBovi® system. In this study, the research selected the Ovi-Bovi monitoring system due to its lower cost and its support for using short messaging service (SMS) alert system which provides current information to the farmer regarding the status of the animal. Based on evidence gained from its utilisation in the field, the research confirmed the feasibility and useability for tracking the pedometric activity patterns of cows for heat detection, lameness detection, or symptoms of illness.

In the meat processing phase, low-cost mobile technologies such as the use of barcode labelling systems, NFC cold chain monitoring solutions and Bluetooth wireless sensors can be utilised to improve carcase labelling, support identity preservation of carcase, transparency of temperature information and to enhance verification of compliance along the cold chain. Although a number of authors have suggested the use of sophisticated smart systems and TTI for supporting traceability (in areas of provenance and meat safety) along red meat supply chains (Biji et al. 2015; Müller et al. 2019).While these technologies are significant, they were found to be impractical for their utilisation amongst the small businesses. In this study, barcode labelling was found to be the most practical for labelling beef carcase in the abattoir, while the use of portable NFC monitoring system was easily deployed in the abattoir and cold chain to improve continuous tracking and monitoring meat temperature during road transport.

In the retail phase, the research found that low-cost technologies such as native mobile apps, progressive web apps, QR code labelling system and wireless sensor temperature monitoring systems can be utilised to support traceability and for responding to challenges related to meat provenance, meat safety, and meat quality. For example, in terms of meat provenance, the use of QR code verification systems integrated using mobile apps was found to improve product labelling and meat verification, marketing and branding of red meat product, improve quality of information aligned to traceability of red meat, and enhance consumer assurance. Within the literature, several studies have reported the feasibility of implementing low-cost mobile technologies such as native apps to support traceability and digital transformation of food supply chains (Pigini et al. 2017), and potentially to enhance safe food management behaviour amongst meat consumer (Bamgboje-Ayodele et al. 2018). This study was able to validate through the multiple case studies the feasibility of utilising native apps and portable wireless monitoring systems as tools to support the digital transformation of red supply chains involving small businesses, and for responding to critical traceability challenges faced in areas of meat provenance, meat authenticity, meat safety.

In terms of meat safety, traceability technologies such as wireless Bluetooth ® sensors equipped with temperature sensing systems were utilised to enhance visibility and transparency of meat temperature within the butcher stores. These technologies have also been confirmed in previous studies to be a useful tool for businesses to support the collection and transmission of micro-environmental information gathered from the surrounding environment (Costa et al. 2013), and along the cold logistics chain (Carullo t al. 2009; Shan et al. 2004). In this research, the wireless sensor systems deployed were utilised for time–temperature monitoring and documenting of traceability along the cold meat chain. Although in previous studies, the system functionality being proposed used RFID based temperature sensors and a GSM/GPRS based communication system, web-based system (Thakur et al. 2015). This study utilised only utilised both RFID sensors and a WiFi/4G network for real-time temperature monitoring during road transportation along the cold chain and within the butcher store. Furthermore, this system functionalities were found to impact the retail butchers in areas such as correcting staff behaviour in organisational operations, enhance organisational awareness, detection, and responsiveness of risks to meat spoilage in the store.

In terms of how low-cost mobile technologies can be deployed amongst small businesses in red meat supply chains, the research finds that utilising a fragmented segment approach is the most practical and feasible strategy to technology intervention amongst the case studies. As this research confirmed, most small businesses operate in Tasmanian red meat supply chain are fragmented, i.e. information and material flow alignment are limited to immediate partners in a chain, in what can be described as OUOD approach. As a result, a fragmented strategy is considered the most effective strategy used to deploy new technologies and to support traceability. This strategy also aligns with the existing framework for traceability (information and material flow alignment) being utilised by the small businesses without disrupting the supply chain in their process of technology intervention. However, in previous studies, numerous authors prefer to deploy new technologies using a more integrated approach, and these include frameworks such as key data elements (KDE) and critical tracking events (CTE) approach proposed by

Zhang et al. (2014); TraceFood framework (Eskil 2313 Foras 2007); FoodPrint framework (Smith et al. 2006), and the generic framework proposed by Regattieri et al. (2007). While these frameworks have proven to be useful in deploying new technologies in integrated supply chains involving large organisations, in this study, the research finds them to be insufficient for understand and supporting traceability amongst the small businesses in Tasmanian red meat supply chains. In deploying the technology, this study also confirms that the intervention using OUOD traceability approach can be organised in three segments, namely:(a) preslaughter (farm-transport-saleyard/processor); (b) slaughter/cold chain (meat processor-cold chain retail); and (c) retail-consumer. These three segments offered the most feasible strategy for effectively deploying IT along the chain. Furthermore, using Step 2 (supply chain mapping) and Step 3 (baseline data collection), it was also possible to identify, select and prioritise traceability challenges within a given segment and to support the development, deployment and trial of the mobile technologies proposed in the chain.

RQ2: *What criteria do small businesses in red meat supply chains use in evaluating the role and potential impact of low-cost mobile technologies in supporting traceability, and for responding to challenges faced?*

Within the research literature, different authors have suggested a wide variety of IQ criteria for evaluating the role and potential impact of IT on traceability both within individual firms and also along the supply chain literature(Wang et al., 1998 ; Zhou, 2009; Molnár et al. 2011; Al-Mamary et al. 2014). For example, Wang et al., (1998) defined IQ across four dimensions: intrinsic IQ, contextual IQ, representational IQ, and accessibility IQ. Golan et al., (2004) described traceability in terms of ‘breadth’, ‘depth’ and ‘precision’. McEntire et al. (2010) introduced a fourth criteria called ‘access’ which refers to the speed with which traced information can be communicated to supply chain members and public health institutions during food emergencies. In the study conducted by Molnár et al. (2011), the authors concluded that IQ criteria for evaluating traceability includes accuracy, relevance, timeliness, reliability, completeness, usefulness, credibility, trustworthiness and being up to date. In the study conducted by Caridi et al. (2010), three information metrics, namely accessibility, accuracy and freshness and currency were proposed. In this study, the exploration research found that small businesses in red meat supply chain utilise markedly different qualitative and quantitative criteria for evaluating the role and potential impact of low-cost mobile technologies on traceability. Quantitatively, the first category is the information quality criteria, *and these include accessibility, freshness and currency of information, accuracy, and format*. Qualitatively, the organisational criteria include organisational awareness, organisational willingness to adopt, organisational behaviour, and organisational responsiveness, branding and marketing. The third criteria relate to consumer awareness.

> ***RQ3:*** How *can a small business traceability framework be developed to support the implementation and evaluation of low-cost mobile technologies to support traceability and for responding to challenges faced?*

The research generated a new small business traceability framework based on validation and further refining of the heuristic's framework utilised to guide the conduct of this study (see section 10.6). This new framework is developed by integrating (a) key findings generated from the multiple case studies; (b) and feedback received from the industry and government stakeholder consultation; and (c) validating the heuristic tool adapted from the work of Caridi et al. (2010). The framework provides new methods for assessing visibility to traceability challenges using information quality metrics aligned to issues of accessibility, accuracy, completeness and format. In previous studies, approaches for assessing traceability using information quality metrics have varied widely amongst authors. For example, in Golan et al., (2004), traceability is evaluated in terms of 'breadth', 'depth' and 'precision'. McEntire et al. (2010) introduced the fourth criteria called 'access'. In Molnár et al. (2011), traceability is assessed using information quality metrics such as accuracy, relevance, timeliness, reliability, completeness, usefulness, credibility, trustworthiness, and being up to date. In this study, the most significant information quality metrics are aligned to issues of accessibility, accuracy, timeliness, and completeness. These information quality metrics provide an alternative proxy measure for understanding and assessing participants perceived level of visibility to traceability challenges and to identify how and to what extent can the utilisation of low-cost mobile technologies be deployed to the critical traceability challenges both within individual businesses and along the supply chain. Based on the framework, the research was also able to evaluate the role and potential impact of IT on traceability both within individual businesses and along the red meat supply chain. A detailed discussion of the new framework is presented in Sections 10.6. In the next section, a critical reflection of the overall case study findings is discussed.

10.3 CRITICAL REFLECTION ON THE OVERALL CASE STUDY FINDINGS

This section presents a critical reflection on the analysis of the overall study findings that emerged from this exploration research. The discussion in this section is organised using the three-phase strategy adopted, namely pre-intervention, intervention, and post-intervention. The next section reflects on the key findings from the industry familiarisation step.

10.3.1 PRE-INTERVENTION (INDUSTRY FAMILIARISATION STEP)

The interactions with industry stakeholders showed that Tasmanian small businesses could be vulnerable to multiple potential traceability challenges that relate to issues of meat provenance, meat safety, meat quality, and animal welfare. Table 20 below summarises these potential traceability challenges that industry stakeholders perceived to be negatively impacting Tasmanian small business in their supply chains. As seen below, the table consists of four main columns, namely: (a) Traceability challenges – describes the potential traceability challenges identified and validated by the industry stakeholders; (b) Traceability factors- these are factors that underpin the traceability challenges faced by Tasmanian small businesses from the perspective of the industry and government stakeholders; (c) Supply chain factors- describes those supply chain management factors that contribute to the potential traceability challenges faced by Tasmanian businesses at different points along the red meat supply chain; and (d) External socio-technical factors-external social, environmental and technical factors which contribute to the poor traceability and exposure to risks and challenges at different points along their supply chains. In the area of provenance, the traceability challenges were found to be linked to issues of compliance, identity preservation, transparency and proof of meat origin. It shows that in the area of provenance, the traceability challenges were found to be linked to issues of compliance, identity preservation, transparency and proof of meat origin. In the area of meat safety, the traceability challenges include issues of risk of chemical residue detection, risk of heavy metal contamination, and risk of microbial contamination, temperature monitoring, and hygiene. In the area of meat quality/authenticity, the traceability challenges relate to issues of meat substitution,

Table 20: Potential traceability challenges impacting Tasmanian small businesses in their supply chains

Traceability challenges	*Traceability factors*	*Supply chain factors*	*External socio and environmental factors*
Meat provenance	Compliance, identity preservation, Transparency and proof of meat origin	Fragmentation, poor harmonisation of multiple traceability, the influence of third-party agents	Poor awareness, poor organizational attitude external poor internet connectivity, equipment malfunction and failure, low digital literacy, poor literacy skills, poor internet connectivity, limited value proposition
Meat safety	Risk of chemical residue detection, risk of heavy metal contamination, and risk of microbial contamination, temperature monitoring, hygiene	Poor agricultural practices, poor records management	Perceived fear of accountability
Meat quality/Authenticity	Substitution and labelling, speciation	Lack of transparency	
Animal welfare	Scheduling and visibility in meat handling operations	Lack of supply chain co-ordination	The high cost of animal transportation

mislabelling, and cases of product speciation/co-mingling. In the next section, a critical reflection for each of these four key traceability challenges potentially affecting Tasmanian small businesses is presented.

10.3.2 MEAT PROVENANCE

The literature highlights several challenges related to meat provenance in red meat supply chains, and these include cases of mislabelling(Pointing et al. 2008; Tonsor et al. 2013), specie substitution(Walker et al. 2013), product misdescription(Woolfe et al. 2004), country-of-origin labelling(Verbeke et al. 2009), compliance(Charlebois et al. 2014), and disease outbreak (Scoones et al. 2010). In this study, the most significant were found to be related to issues of compliance, identity preservation, transparency and proof of meat origin. The section presents an interpretation of the key issues of meat provenance potentially affecting Tasmanian red meat supply chains.

10.3.2.1 COMPLIANCE

Compliance relates to the capacity for firms to meet the minimum standards and requirements prescribed for mandatory registration of cattle and sheep from birth to death. It also prescribes minimum standards for information sharing related to the traceability of the red meat along the supply chains. The industry stakeholders stated that the minimum requirement for traceability is based on OUOD approach that that limits information sharing to immediate partners. The research literature also confirms that most small businesses in the red meat industry utilise the OUOD approach (Mattevi et al., 2016a), in part because of the limited technological overhead and simple data requirements involved with capturing sharing traceability information in the chain. In the study conducted by Zhang et al. (2014) on traceability and small businesses, the authors found that this OUOD approach does not provide enough incentive for actors to share complete information on traceability and the chain and thus opens up possibilities to issues of provenance and poor visibility. In this study, the industry stakeholders considered the minimum OUOD requirement sufficient for understanding traceability in the chain., yet many believe there are still issues with compliance to this minimum requirement in the Tasmanian red meat industry.

10.3.2.2 CHAIN FRAGMENTATION AND MULTIPLE STANDARDISATIONS

The issue of chain fragmentation relates to the silo structured of information sharing in the red meat supply chain, and this is believed to occur at two key segments- the pre-slaughter (farm to the processor) and post-slaughter (processor to retail). In the literature review conducted in this study, one report from the Australian Department of Industry & Science highlighted this issue of fragmentation as significantly impacting traceability and information sharing amongst small businesses in the red meat supply chain[42].The report by the AMIC also reported the issue of fragmentation as a major traceability challenge impacting the productivity and performance of most businesses operating in the red meat industry[43]. This study confirmed from the industry stakeholders that part of the issues of traceability with small businesses is the fragmentation of their supply chains, mostly in the pre-slaughter (farm-meat processor-retail) and post-slaughter (meat processor-cold chain and retail butcher). In this study, the issue of fragmentation was found to be much broader, covering 4 key areas, namely: (a) regulatory fragmentation, i.e. multiple traceability standards and requirements which might confuse many small businesses. This study linked this issue to the problem of multiple traceability standardisation in the industry and lack of a sound common theoretical framework along the red meat supply chain (Karlsen et al. 2013).; (b) information fragmentation relates disparities in the quality of information generated and shared at different parts of the chain. Solanki et al. (2013), in their study, highlighted that this challenge was related to approach to information capture and sharing, in what can be described as a silo structure. This study confirms that silo structure indeed could be contributing to issues of fragmentation along different points of the red meat supply chain; (c) operational fragmentation, i.e. poor integration of supply chain operations for planning and scheduling. In most food supply chain, these challenges have been linked mostly with food logistics (Lowe et al. 2009). In this study, the critical issue relates to operational fragmentation, particularly with regards to planning and poor scheduling in the pre-slaughter segment of the red meat supply chain; and (d) technology fragmentation, i.e. lack of integrated flow of technologies for managing information at different points in the

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[42] http://limestonecoastredmeat.com.au/wp-content/uploads/2015/11/AusIndustry-mapping-report-public-version.pdf

[43] https://www.ampc.com.au/uploads/pdf/strategic-plans/42161_AMPC_RiskDocumentvLR.pdf

chain. Previous studies by Mattevi et al. (2016a) and Zhang et al. (2014) have reported similar challenges in relation to poor technological integration amongst the small business in relation to traceability. However, in this study, this issue of technology fragmentation is also due to external socio-technical barriers.

Previous studies that have explored barriers to IT traceability amongst small businesses highlight a number of key issues such as (a) lack of awareness of and education on the need for traceability technology, especially at the full-chain level; (b) Knowledge gaps of what full-chain traceability is and what full-chain digital traceability does; (c) Poorly demonstrated incentives for creating buy-in to the value full-chain digital traceability can offer; (d) Resource deficiencies, including funding and capacity issues; (e) Technical issues with information technology (IT) systems and data management; (f) Logistical hurdles in the operation of traceability systems; and (g) Scaling issues in promoting and achieving broader adoption (Bosona et al. 2013; Hardt et al. 2017; Xue et al. 2007; Zhang et al. 2011). In this study, external socio-technical factors include issues of poor awareness, poor organisational attitude, poor internet connectivity, equipment malfunction and failure, low digital literacy, poor literacy skills, poor internet connectivity, limited value proposition. This research provides additional context for understanding and mitigating challenges related to external socio-technical factors impacting traceability amongst small businesses in red meat supply chains.

The issue of multiple traceability standardisation relates to the lack of harmonisation of data and information requirements at different in the red meat supply chain. Previous studies have also highlighted the issue of standardisation as a significant barrier impacting traceability in most red meat supply chain (Karlsen et al., 2013). In this study, the industry stakeholders believed that some of the traceability challenges faced by small businesses could be linked to the lack of harmonisation and multiple standardisations of data amongst different regulatory bodies in the state. It was also suggested that this lack of a common framework for implementing traceability contributes to some confusion amongst small businesses in distinguishing between minimum mandatory requirements and voluntary requirements for red meat traceability along the supply chain. The research also found that the lack of a common framework for implementing traceability contributes to some confusion amongst small businesses in distinguishing between minimum mandatory requirements and voluntary requirements for red meat traceability along the supply chain. In a previous study conducted by Mattevi et al. (2016a) and Zhang et al. (2014), the issue of standardisation of data and information in traceability were linked to both technological and regulatory. However, what this research finds that while technology is a barrier, the key issue of the inability for different agencies to harmonise information and data requirements in ways that allow for seamless capture and exchange of information amongst supply chain actors and the different regulatory bodies.

10.3.2.3 IDENTITY PRESERVATION AND VERIFICATION OF MEAT ORIGIN

The issue of identity preservation *(IP)* has been explored and interpreted in different supply chain contexts, most commonly with regards to product segregation, differentiation and labelling (Lusk 2001). Previous studies have also linked IP to poor labelling(Pointing et al. 2008; Tonsor et al. 2013), poor specie substitution(Walker et al. 2013), product misdescription (Woolfe et al. 2004), geographical labelling(Verbeke et al. 2009). Although no broad definition of traceability has emerged(Van Dorp, 2002), this traceability challenge of IP can also be linked to issues of product traceability (Opara,2003). In particular, these product traceability challenges relate to animal identification, labelling and information sharing along the supply chain. However, other issues linked to identity preservation were also identified including non-compliance and negative organisational attitude. However, there were other issues that underpin IP amongst most Tasmanian red meat supply chain involving small businesses and these were found to be related to non-compliance and negative organisational attitude towards information and records management. Amongst these issues, the research found that negative attitude amongst some business owners poses the most significant risks to traceability and IP along the red meat supply chain.

The issue of verification of meat origin (VMO) was identified as another significant traceability challenges linked to meat provenance. When considering this challenge in the context of the seven dimensions of traceability suggested by Opara (2003), this can be linked to issues of product traceability. According to Opara (2003), product traceability determines the physical location of a product at any stage in the supply chain to facilitate logistics and inventory management, product recall and dissemination of information to consumers and other stakeholders. While this specific challenge of VMO is linked to *geographical farm traceability, this research also confirms that the lack of adequate technology infrastructure also underpins it. Furthermore, while literature highlight issues of* geographical farm traceability focus on ascertaining the geographic region of the farm in which an animal is raised(Guo et al. 2010), this study views geographical traceability in the context of the geographical zone or state of origin from where the animal is grown, raised, fed, or slaughtered within Australia.

10.3.3 MEAT QUALITY/AUTHENTICITY

The research literature highlights multiple traceability challenges related to meat quality, and these include inability to support specie determination of meat products(Song et al. 2019); verification of lifestyle products (e.g. vegetarianism and organic food), authentication of food based on religious requirements (e.g. absence of pork from some diets), or diet and health concerns (e.g. absence of allergens) (Ballin 2010).Other challenges such as the physical and structural quality verification of meat(Biswas et al. 2020), adulteration(Mai et al. 2019), accreditation and certification verification such as the case of Halal(Al-Teinaz et al. 2020; Zulfakar et al. 2019) and Kosher(Holloway et al. 2019). In this study, only 3 critical challenges were found to be the most significant and these include issues *of meat speciation, mislabelling and meat* substitution. Furthermore, the traceability challenges related to meat quality amongst small businesses is linked to one or more problems including: (a) ascertaining the composition of the ingredient within the meat product; (b) providing appropriate labelling of product concerning the origin of raw materials; and (c) cases on comingling of meat products. The research also confirmed amongst the industry stakeholders, only three areas of meat quality have confirmed cases associated with small businesses i.e., *meat speciation, mislabelling and meat* substitution.

Within the research literature, a number of key issues related to meat along the supply chain have been widely discussed (Ballin 2010). Prominent challenges mentioned in relation to meat quality have been linked to meat fraud in areas such as: (a) the inability to authenticate the origin of meats and the animal feeding regime used to grow the animal (as in the case of regional certificated products, for example); (b) substitutions of meat ingredients by other animal species, tissues, fat or proteins; (c) modifications of the processing methods of meat products and 4) additions of non-meat components such as water or additives (Ballin 2010). In this study, the research confirmed that the traceability challenges related to meat authenticity could be linked to negligence on the part of the retail butchers, rather than intentionality to commit fraud. This research also finds that this issue is particularly prevalent in the retail segment, given the increased importance and potential opportunities that exist to utilise product attribute information for marketing, and branding in the store. In previous studies, traceability challenges related to issues of meat authenticity have been linked to improper product marketing and branding(Teixeira et al. 2019), thus confirming the perceptions held by the industry and government stakeholders in Tasmania concerning vulnerabilities of small retail butchers to issues of meat quality and authenticity.

10.3.3.1 MEAT SAFETY

Within the research literature, potential traceability challenges related to meat safety in red meat supply chains have been linked several key issues, such as (a) risks and vulnerability of spoilage due to microbial contamination (Nychas et al. 2008; Saucier 2016) and growth of pathogens(Leger et al. 2004); (b) poor hygiene (Ghafir et al. 2008); (c) poor processing conditions(Sumner et al. 2011); (d) inability to support meat recall(Shang et al. 2017);(d)compliance/quality assurance/meat inspection(Butler et al. 2003) and HACCP compliance (Horchner et al. 2006);(e) detection of chemical/antibiotics residue (Alla et al. 2013); (e) poor packaging techniques (Sebranek et al. 2006); and (f) reduction in shelf life(Emanuel et al. 2020).However, in this study, only four main traceability challenges linked to meat safety were identified, and these are *issues of chemical residue detection, heavy metal contamination, microbial contamination in meat products, and temperature abuse in cold chain logistics operations*. In the framework proposed by Molnár et al. (2011), the authors further distinguished between meat safety issues affecting red meat supply chains in three areas, and these are compositional, biological, and technological. The compositional category comprises of (a) chemical hazards, e.g. heavy metal composition, (b) biological hazards, e.g. microbial pathogens; and (c) analytical, e.g. accreditation. The technological category relates to the transport and distribution (e.g. temperature control). Based on this framework, the research confirmed that only 1 category of traceability challenges related to meat safety were confirmed to be potentially affecting Tasmanian small businesses along different points of the red meat supply chain, and this relates to **compositional factor**. The first compositional factor relates to the potential for microbial meat contamination in the chain. The risk sources perceived by industry stakeholders to be contributing to cases of microbial meat contamination include poor processing conditions, temperature abuse, cross-contamination, and issue of poor staff hygiene (Chung at al. 2020; Girish et al. 2020). The second compositional factor is the possibility of chemical residue detection in meat products. Chemical residue detection is widely acknowledged as a significant food safety challenge in the red meat industry (O'Keeffe et al., 2000; Mitchell et al., 1998). However, specific examples with small businesses in mind remain limited for small businesses. In this study, possibility of chemical residue detection in meat products were linked to poor compliance by some farmers concerning maintaining withholding periods of animals treated with antibiotics.

Another significant traceability challenges linked to meat safety is the possibility of heavy metal contamination in meat products. Heavy metal contamination, while very rare in red supply chains, has been discussed widely in the research literature(Ahmad, 2016). However, very few focus their attention on how this traceability challenge affects small businesses. Cases of heavy metal contaminants have been attributed to natural and anthropogenic sources (Ahmad, Makridis et al., 2012). However, no specific examples exist for small businesses. This study confirms from industry stakeholders and government agencies that the possibility of heavy metal contamination within small businesses can be linked closely to anthropogenic or external sources such as poorly incinerated tools and salvage equipment, and lead battery contamination. The research also finds that the most vulnerable supply chain segment is the farm production phase.

10.3.4 ANIMAL WELFARE

One industry stakeholder linked challenges of animal welfare to poor scheduling, inadequate supply chain co-ordination and lack of visibility of operations. Although these factors have been discussed extensively with larger businesses in integrated chains (Grandin, 2007; Greger, 2007), very few insights have been generated concerning how this affects small businesses. In this study, one industry stakeholder believed that **improper scheduling and lack of visibility of operations** are some of the major cause of poor animal welfare along the chain, with cases known to include the stress of cattle and loss in meat quality in the Tasmanian red meat industry. These findings have also been reported in other studies (Grandin, 2007, Greger, 2007), and were confirmed to be a significant challenge for most small businesses operating in the Tasmanian red meat supply chains. For example, in the study conducted by Grandin (2007), the author found that poor visibility of trucks operations could impact animal welfare in several ways including social regrouping, crowding, climatic factors (temperature, humidity, and gases), restraint, loading and unloading, time of transit, and feed and water. In this study, transit time and social grouping were identified as the most significant stressor for most cattle in Tasmanian red meat supply chains.

Within the research literature, potential traceability challenges related to animal welfare have linked to a number of socio-technical problem such as poor transportation and handling(Castro et al. 2019); poor lairage conditions(Rudra et al. 2019); transportation time (Mendonça et al. 2019), exposure to stressful transportation regimes(Carrasco-García et al. 2020), poor training and knowledge of abattoir stakeholders (Descovich et al. 2019), and incidents of bruising of the carcase (Bethancourt-Garcia et al. 2019). In this study, only 3 of these challenges are confirmed to be potentially affecting Tasmanian small businesses along the chain, and they include (a) *issues of* ***poor scheduling; (b) inadequate supply chain co-ordination; (s) and lack of visibility of operations***. In terms of poor scheduling, the research found that the process for organising transportation of animals was rather opportunistic rather than systematic. In this context, the farmers do not have control and visibility over times and duration of transport of cattle and consequently lack visibility of operations in this chain. One industry stakeholder suggested that this issue of poor scheduling and limited visibility of operations poses significant risks to meat quality and potential loss in meat value for most local farmers. In previous studies a wide range of factors aligned to challenging stimuli affecting animal welfare have also been identified (Grandin 2007). These includes noise, vibration, social regrouping, crowding, climatic factors (temperature, humidity, and gases), restraint, loading and unloading, time of transit, and feed and water deprivation have been found to negatively affect the welfare of beef cattle during transportation (Ferguson et al. 2008).While these range of stimuli are known to affect most beef cattle and sheep, only 2 challenges linked to transit and social grouping were found to be of critical importance to the small businesses in terms of traceability..

Another critical issue raised by the industry stakeholder relates *to poor visibility of trucks operations*. This relates to the inability of a farmer to monitor essential parameters of welfare that have a significant impact on animal welfare during road transportation. For example, Schuetze et al. (2017) identified 5 critical parameters that can be used to characterise and monitor welfare condition of animals along the supply chain and they are: microclimate environmental condition, loading density, duration of transport, quality of transport, and animal behaviour. Based on the interaction with the industry stakeholders, two critical parameters were identified as being the most significant for monitoring animal welfare, and to verify compliance to issues of poor animal conditions during road transport. These parameters include ***quality of transport (i.e. transit times) and animal behaviour***. The ***quality of transport*** was found to be linked to the inability to monitor critical parameters such as animal loading and unloading activities, longer lairage times, and more extended journeys periods (Gallo et al. 2003). The issue of animal behaviour includes the inability to monitor animal temperament, movement, and noise during entire transportation. The research also found that changes in animal behaviour are also linked to the mixing of cattle and holding times at the abattoir because they are critical control point during logistics operations. These factors were considered the most significant traceability challenges amongst small businesses in relation to animal welfare from an industry perspective.

10.3.4.1 SOCIO-ENVIRONMENTAL FACTORS

Socio-environmental factors are those external social, organisational/environmental, and behavioural factors that influence the ability for small business to support enhanced traceability the different segment in the supply chains. In this study, the key socio-environmental factors impacting traceability amongst small businesses include: (a) business value proposition;(b) organisational awareness and attitude;(c) internet connectivity/technology penetration; (d) technology literacy. In terms of business value proposition, the research found that amongst the industry stakeholders, especially with local hubby farmers, many do not take traceability seriously because of the lack of perceived value and importance of the existing NLIS system. Amongst the industry stakeholders interviewed, many hold the opinion that local farmers still exhibit a limited understanding of the importance of mandatory tagging of animals at birth, documentation of farm production records, and ensuring timely update of information to NLIS database. However, these findings are in contrast to the results obtained from Mattevi et al. (2016b), where the authors found that amongst small businesses exhibited there were some that show a moderate to a high level of awareness and understanding of the importance of traceability even though only very few possessed sophisticated technologies.

Some of the stakeholders raised the issue of internet connectivity. The key points were that because most local hubby farmers reside in remote areas of Tasmania, many local still face the problem of poor internet connection and this may be contributing to the lack of interests in the use of digital technologies. It is also believed that poor internet connectivity impacts negatively on the capacity for smallholder farmers to comply with the timely upload and sharing traceability information on the NLIS system. These findings confirm another previous study conducted by Tasmania's Department of Premier and Cabinet (DPAC)[44], on digital penetration in Tasmania. The report revealed similar results concerning how poor internet connectivity in Tasmania significantly affects the capacity for small businesses to innovate and participate in the digital economy. Another significant socio-technical factor highlighted by some industry stakeholders is ICT literacy and limited educational attainment. For most small businesses, it was discovered that the lack of education and literacy contributed to poor traceability utilisation and adoption. This socio-technical factor of literacy has been reported by Stockdale (2003), as some of the critical barriers limiting IT use and adoption amongst small businesses. This study confirms that digital literacy contributes to limited traceability and inability to respond to critical challenges at different points of the red meat supply chain.

10.3.5 SUMMARY OF INDUSTRY FAMILIARISATION STEP

The industry familiarisation phase of this study provides new insights that could be valuable for understanding and exploring issues of traceability amongst small businesses along the red meat supply chain. Several key findings emerged from the interaction of the stakeholders concerning potential challenges related to meat provenance, meat safety, meat quality, and animal welfare. In the area of provenance,

[44] http://www.dpac.tas.gov.au/__data/assets/word_doc/0006/109941/Appendix_1_-_Data.doc

the research found issues of verification of origin, and identity preservation as being the most critical areas that could impact small businesses in terms of traceability risks. These challenges are also linked to the fragmentation of the red meat supply chain, especially at the pre-slaughter and post-slaughter segments.

In the area of meat safety, the research found that the potential traceability challenges were related to chemical residue detection, heavy metal contamination, microbial contamination/cold chain monitoring. In the area of animal welfare, the industry stakeholders mentioned that that small business could be exposed to risks of improper handling/ exposure of cattle to stress-related conditions as a result of poor visibility of operations and inefficient scheduling. While the issue of animal welfare remains very complex and undoubtedly a critical area of concern in the Tasmanian red meat industry, there is yet to be a practical approach for monitoring and mitigating the risks associated with stress and potential loss in meat quality along the logistics chain. In terms of meat quality/authenticity, the key issues include substitution,mislabelingof meat product, and improper designation of compositional attributes of food. The research also identified multiple socio-environmental factors that contribute to limited traceability amongst small businesses. They include poor organisational awareness and attitude, digital literacy, and poor internet connectivity. These factors were also contributing low levels of compliance amongst small businesses in the Tasmanian red meat supply chain.

10.4 PRE-INTERVENTION -SUPPLY CHAIN MAPPING STEP

10.4.1 FARM PRODUCTION

In the farm production phase of the red meat supply chain, the most significant traceability challenge was found to be related to animal welfare, in two key areas: (a) the ability to monitor animal behaviour/animal wellbeing, and to improve detection of oestrus.; and (b) environmental sustainability. In the area of animal welfare, the research literature has been concerned over 3 key questions in the farm production phase, and these are: (a) Is the animal functioning well (e.g., good health, productivity)?; (b) Is the animal feeling well (e.g., absence of pain.); and (c) and Is the animal able to live according to its nature (e.g., perform natural behaviours that are thought to be important to it, such as grazing)(Von Keyserlingk et al. 2009). These questions underpin some of the most critical traceability challenges of animal welfare along the beef supply chain. In this study, the research found the first two questions to be the most critical, in terms of animal functioning well (e.g., good health, productivity)? To enhance animal productivity and consequently improve welfare, one of the key focus of the farmers in this study has been to maintain visibility of behavioural movements of the cows on the farm and to ascertain whether changes are indicative of oestrus or readiness for mating.

Previous studies have shown that cows exhibit marked changes in behavioural patterns during the heat and this changes in behaviour could be utilised for ascertaining the readiness for mating with bulls or artificial insemination(McGowan et al., 2007). Approaches to oestrus detection in the farm include techniques such as physical, veterinary, and sensor-based evaluation (Roelofs et al., 2005). In this study, the farmer currently utilises visual/physical observations for monitoring behavioural changes in cattle. This approach, while helpful, is known to be unreliable in detecting cows in oestrus and could pose significant risk of economic and operational loss due to farmers due to the strong possibility of false detection of oestrus and late identification of illness in cattle(Dawkins, 2004). Other key issues mentioned include (1) Unexploited potential of calf production by prolonged calving intervals; (2) expenditures on the hiring of bulls; (3) and reduced rate of genetic progress due to failed detection of oestrus. However, in this study, one of the farmers did not perceive the use of visual approach to be a significant challenge to maintaining visibility to animal welfare, despite its limited capacity to support traceability and to monitor animal behaviour in the farm. Instead, the farmer maintained his view that visibility using the frequency of visits to the farm could be used to monitor animal welfare.

However, in the lamb meat supply chain, the farmer was more interested in *environmental sustainability*. This focus on traceability that aims to achieve sustainability objectives has been defined as “traceability for sustainability”(Garcia-Torres et al., 2019). Environmental sustainability in farm production involves the integration of sustainability goals, i.e. social, environmental, and economical in the production of food. Approaches to achieving these goals have usually been linked to a holistic and integrated supply chain management approach that involves the participation of all actors(Lazarides et al., 2018). This integrated approach is also defined in terms of a number of operational initiatives such as (a) efficient production and processing system; (b) distribution systems that protect the quality, assure safety, and promote the fair and transparent distribution of created value; (c) consumer access to wholesome-healthy food at acceptable prices; and (d) and sustainable development of rural communities(Lazarides et al., 2018).

However, in this study, the traceability for sustainability exhibited by the lamb farmer is limited *to the farmer/transportation phase*. Furthermore, this study confirmed that motivation for engaging in traceability for sustainability *could also be explained through these three factors,: (a)* ***social factors*** (i.e. ethical responsibility in livestock production, e.g. minimising stress and physical harm on animals, free-range, grass-fed, non-antibiotics, proper documentation of veterinary inputs, minimising distance travelled for livestock processing); (b) ***environmental*** (maintaining plant biodiversity in the farm through the planting of new trees, sheds for animals); and (c) ***economic factors*** (i.e. job creation, perceived opportunity for marketing, branding, product differentiation, and value-add). The research also found that the farmer's educational background played an important role in business prioritisation and sustainability focus of traceability.

Another key finding that emerged in this phase relates to the categories of potential traceability risks and challenges associated with animal welfare in the farm production stage of the chain. Most studies that focus on issues of animal welfare in this segment highlight several key concerns such as: (**a) technical concerns-** (i) poor transportation and handling(Castro et al. 2019); (ii) lairage conditions(Costa et al. 2019; Rudra et al. 2019); transportation time(Mendonça et al. 2019); (iii) stress(Carrasco-García et al. 2020); (iv) incidents of bruising of the carcase(Bethancourt-Garcia et al. 2019); and (b) **non-technical concerns** such as (i) poor training and knowledge of abattoir stakeholders(Descovich et al. 2019). In this study, concerns related to potential traceability challenges of animal welfare were found to be aligned to 2 key areas alone, and these were : (a) concerns over the possibility of stress and compromise of animal welfare using third party transport; (b) maintaining family tradition; (c) creating entertainment experience for children; (d) size of business; (d) perceived impact on meat quality. These factors were confirmed to be a mixture of technical and non-technical, indicating that amongst small businesses, issues of animal welfare are more qualitative than being quantitative.

Significantly, the research also found that while participants at the saleyard did not perceive any challenge with current scheduling practices, there were several supply chain management challenges which impacted traceability and this was related to poor scheduling. Some studies(Romero et al., 2013; Schuetze et al., 2017) have confirmed that inadequate scheduling poses significant risks to the welfare and ultimately impact meat quality. One likely explanation for this supply chain management challenges related to scheduling of cattle transport is the *poor coordination of the pre-slaughter* segment of the red meat supply chain. Because small businesses tend to operate independently, they are challenged by the lack of coordination and inability to support specialised supply chain management functions such as planning and control *(Katunzi et al., 2010).*This issue of scheduling was also mentioned by one government stakeholder in terms of some of the underpinning issues of animal welfare amongst small business, thus confirming the traceability along the red meat supply chain.

10.4.2 MEAT PROCESSOR, WHOLESALE AND COLD CHAIN LOGISTICS

In this phase of the red meat supply chain, the most significant traceability challenges were found to be aligned to issues of meat provenance and meat safety, and both traceability challenges are further linked to issues of *non-compliance*. Within the literature, traceability challenge related to meat provenance have been treated in different contexts, while covering a broad range of problems including (a) inability to ascertain meat geographical origin, farm production system and properly maintain a record of a meat's journey from the farm to the consumer's table(Monahan et al. 2018; Osorio et al. 2011); the problem of poor animal identification through proper labelling of meat (Pointing et al. 2008; Tonsor et al. 2013), product misdescription(Woolfe et al. 2004), country-of-origin labelling(Verbeke et al. 2009), and compliance(Charlebois et al. 2014). While these concerns are very significant in most red meat supply chains, in this study, only very challenges were found to be substantial for small businesses.

In the meat processor, the most critical traceability challenge related to meat provenance were found to be linked to issues of poor *labelling and identity preservation*, i.e. the inability of to preserve the identity of carcase and main proper alignment between RFID identification and carcase identified after slaughter labelling (Smith et al. (2008). This is because the abattoir adopts a tattoo identification system to maintain traceability of carcase in the abattoir. Tattoo identification systems is known to exposes meat processors to major risks of meat substitution and mis-identification of carcases(Caja et al., 2004, Awad, 2016).Despite these risks, the participant does not perceive a significant traceability challenges of using a tattoo to identify carcase in the abattoir, suggesting low risks perception.

There was also issues of lack of animal identification underpinned by lost RFID tags that was reported by the participant in the abattoir. This traceability challenge involving possibilities of lost RFID tags that are normally attached to cattle during their movement between properties confirms the statement made by one industry stakeholder concerning key issues of provenance impacting local meat abattoirs in the Tasmanian red meat supply chains (*See section 4.2.1.2, Participant P01*). This industry stakeholder mentioned that amongst small meat processors, it is not uncommon to find cases where RFID tags assigned to an animal has been lost and as a result lifetime traceability were not preserved in the chain. In the area of meat safety, keys issues were concerns over *proper hygiene, temperature monitoring and general cleanliness of the abattoir*. However, the most important were (a) inappropriate chilling regimes above 5^{o}C, which could lead to spoilage in the slaughterhouse.

Along the cold logistics chain, traceability challenges have been widely documented within literature, and these challenges primarily relate to the inability to: (a) monitor refrigerating performance (Brizzi et al. 2013).; and (b) minimise spoilage and maintain shelf life(Nastasijević et al. 2017), and (c) maintain compliance (Zorpas et al. 2010). Amongst these key issues mentioned, the most critical for the meat processor was found to be linked to the inability for supply chain partners (i.e. meat processor, cold chain/retail butcher) to gain visibility and accurately monitor refrigerating performance during road transportation along the chain.

A key observation that emerged within the wholesaler relates to the negative belief held towards the value and importance of MSA based traceability for meat quality. The participant felt that the MSA grading system lacks transparency in terms of the amount and quality of the information provided to consumers to support authenticity and the traceability of meat product in the store. However, this finding is in contrast to earlier studies that have confirmed that previous studies that have suggested that the MSA grading system is a transparent and traceable approach to meat quality/authenticity and system for ascertaining the extrinsic and intrinsic qualities of meat products (Watson et al., 2008).In this study, the wholesaler holds the belief that MSA is not transparent enough for the consumers to make effective purchasing decision due to the lack of complete traceability of the meat product.

10.4.3 RETAIL BUTCHER

Three significant traceability challenges were identified in the retail butcher stage of the chain, and they are related to (a) meat safety (i.e. inability for the retail butcher to maintain visibility of the cold chain and to minimise risks of temperature abuse during transportation); (b) meat provenance, i.e. verification of meat origin; and (c) meat quality/authenticity, i.e. marketing and branding. Within the research literature, traceability challenges related to these three key areas have received very limited attention, particularly for small local retail butchers. In some studies, traceability challenges amongst small retail stores were linked to 3 main areas, and these are: (a) ability to enhance consumers experience, food choice and purchasing decisions in the store (Carpenter et al. 2001); (b) improve marketing using extrinsic quality indicators such as the colour, marbling and tenderness (Feuz et al. 2004); and (c) minimising risks and exposure to product commingling, false labelling, and improper labelling that can result in improper speciation of ingredients in meat products. In this study, amongst the retail butchers explored, some of the most critical traceability challenges related to meat provenance were found to be associated to limited or lack of meat labelling and inability to provide verification and/or proof of meat origin to consumers. In the area of meat safety, the most significant challenges were found to be related to poor visibility to meat temperature along the logistics chain and within the retail store. In terms of meat quality and authenticity, the most significant potential traceability challenges relate to the limited marketing and branding and inability to support authentication of meat products. This study also finds that, amongst these categories of challenges identified, the most significant in terms of meat quality and authenticity were aligned to the inability to capture and utilise value-add information from red meat production to support product marketing and branding using extrinsic qualities of the meat products such as colour, grade, freshness etc.

10.4.4 BARRIERS TO IT TRACEABILITY AMONGST SMALL BUSINESSES IN THE RED MEAT SUPPLY CHAIN

Amongst the small businesses explored in this study, the research found that IT use and adoption to support traceability at different points of the red meat supply chain remains very low. The research found that 3 major barriers contributed to this low IT use and adoption and significantly affected the ability for the small businesses to respond to some of the most critical traceability challenges faced in the chain. These barriers include *organisational, supply chain (inter-organisational) and external environmental factors.*

10.4.4.1 ORGANISATIONAL BARRIERS

Organisational factors are those organisational and job factors that influence individual perceptions and capacity to utilise IT to support traceability along the supply chain (Galliano,2008). Several reasons believed to be why small businesses fail to innovate their businesses with new technologies have been suggested within the research literature (Wagner et al., 2003). Key amongst them include the structures of the supply chain in which they operate, resource limitations, lack of familiarity with the technology and its benefits, lack of technology prioritisation(Vaaland and Heide, 2007).In this study, some of the organisational barriers include the perceived *low volume of business transactions, poor attitude and behaviour, and lack of interest.* These barriers were found to be significant contributors to the limited use of technologies in the supply chain. There was also a marked difference in individual perception of the value of IT, and the adoption of IT amongst the small business owners in the red meat supply chain. In the farm and processor segment, both participants believed limited. IT was sufficient, and both did not see value in innovating their traceability practices. In the farm, significant barriers observed included *perceived lack of trust in new technologies, poor awareness regarding the availability of low-cost alternative technologies, organisational attitude, limited knowledge and poor value proposition*.

However, within individual businesses, specific organisational factors were affecting IT use along the red meat supply chain. For example, in the farm production phase, the research also found specific **organisational factors** that potentially affect IT utilisation with the farmers and these are: (a) perceived small size of *business; (b) employment status of the farmer; (c) organisational attitude; and (d)role of third-party agents*. ***In terms of business size,*** the research found that because some participants considered their businesses a hubby, they did not see any justification for investing in new technologies in their supply chains. Keskin et al. (2018), in a similar study, investigated the relationships between businesses size and IT use adoption. The authors also found that adopters of new IT in the farm operations have tended to be linked with large businesses while non-adopters of new IT tended to have small farms. This research confirms the possible relationship between organisational size and intention to adopt new technologies.

In terms of the employment status, previous studies have shown the existence of a relationship between firms' owner employment status and IT utilisation and adoption. For example, in the conducted by Sharma et al. (2019) with Irish beef cattle farmers, the authors that also found a similar relationship between employment status and technology use and adoption amongst farmers. Their survey revealed that part-time farmers are less likely to adapt to new technology because they earn less from farming and are not sure about its return of investment. In this study, a similar relationship is found in the farm production phase. Because the farmer (i.e. in case study 1) considered himself a part-time farmer, he could not see any value in investing new technologies on the farm. ***In terms of awareness,*** a number studies such as those conducted by Harker and Anderson (2002) and Taylor and Murphy (2004), confirm that lack of awareness and understanding of the IT remain significant barriers facing most small businesses. In this study, the research discovered similar findings, particularly with one farmer that held the belief that tagging animals are only necessary during a livestock transaction, thereby suggesting the possibility of inadequate lack of adequate knowledge and limited understanding of compliance requirements for red meat traceability. This belief is in contrast to the compliance requirements stated by one industry stakeholder (*Participant P01*) in the industry familiarisation phase concerning registration of cattle at birth till final slaughter (*See section 4.2.1.1*). It also confirms the perception held by some stakeholders concerning the lack of awareness and understanding of traceability system amongst hubby. In the butcher store, there were also specific organisational factors that impacted IT use and adoption. For example, amongst retail butchers, IT use was relatively low, and the reason for this low adoption could be attributed to the *poor attitude of the participant concerning the role of IT in-store operations*. The relationship between organisational attitude and limited IT use and adoption in small businesses have been widely researched with the research literature, and there appears to be a very strong relationship between the two concepts (Taylor, 2019). This study also confirms the presence of a very strong relationship between negative organisational attitude towards IT and low IT use and adoption to support traceability both within individual firms and also along the supply chain.

In the abattoir, specific organisational factors found to underpin the limited use of IT in the processing operations were identified, and these include the *perceived cost of technology acquisition, implementation and maintenance time and cost, and limited value proposition played important roles in inhibiting the use of technologies in the meat processor.* Although the meat processor exhibited some level of technology awareness concerning opportunities to improve traceability using new IT, these factors were the main barriers found to influence the existing business decision and investment in new traceability technologies in the processing plant. Within the research literature, these factors have also been widely reported (Kelepouris et al., 2007, Mattevi et al., 2016a), and appears to be a significant barrier within the meat processor.

The issue of poor organisational awareness has been raised in the recent research literature as having a significant impact on IT utilisation to support traceability (Mattevi and Jones 2016). In this study, there is evidence to suggest that many small businesses fail to capitalise on important information related to meat quality to add value due to lack of awareness of the use of IT for *product differentiation and marketing, including their limited awareness and understanding of how MSA system works. In one case study, for example,* a key observation *related to the* lack of awareness *is observed within the retail butcher phase, where it appears that the participants could not understand how to* apply MSA graded information for marketing ad branding of meat graded as MSA by the meat processor. This is despite the availability of the information on MSA marketing of meat found on the Australian Butchers Guild website[45], where it was explicitly mentioned that retail butchers that purchase MSA graded beef could utilise the MSA brand as part of marketing and product differentiation. *These findings are in contrast to the previous survey conducted by* Mattevi and Jones (2016), where the authors reported that amongst small businesses many only moderate to a high level of awareness of the benefits of traceability.

[45] http://www.australianbutchersguild.com.au/Meat-Standards-Australia

10.4.4.2 SUPPLY CHAIN BARRIERS

This research identified 2 supply chain barriers that influence low IT traceability utilisation amongst the small businesses along the red meat supply chain. These barriers include (a) strong supply chain relationships held with key red meat industry businesses in Tasmania (i.e. farmers, stock agents, sale yards, meat processors, cold chain) underpinned by supply chain trust) and strategic sourcing alliances held with clients, i.e. butchers and farmers; and (b) supply chain structure; and information quality. In previous, for example, in Jie et al., (2007), the authors identified 5 main barriers known to impact supply chain management in the red meat sector. In their study, the key barriers identified include *strategic supplier partnerships, customer relationships, information sharing, information quality and a lean system*. While there exist similarities in the findings of this study with those conducted by Jie et al., (2007), the contexts in which they appear are different

Firstly, in terms of supply chain relationships, various dimensions of supply chain relationships (such as trust, commitment, adaptation, communication and collaboration) have been suggested within the research literature as having a potential impact on traceability and supply chain performance (Fynes et al., 2005). In this study, **trust and communication** are the two key dimensions of supply chain relationships were the most significant to traceability and are believed to influencing the capability for the wholesaler to ascertain traceability in the chain. However, trust was found to limit business interests in IT utilisation along the chain. For example, amongst some local butchers, many could not perceive any significant risks and challenge with traceability in the area of meat safety (i.e. temperature visibility along the cold logistics chain), partly due to the perceived trust, *confidence in business reputation, and supply chain relation quality between the butcher store and the transport operator*. Previous studies have also reported on the role of traceability as a mediator in building trust amongst actors and promoting confidence food supply chains (Sarpong, 2014, Choe et al., 2009, Hobbs, 2003b). However, in contrast to these studies, this research finds that supply chain trust that exists between actors in limited the incentive for enhanced temperature traceability using new IT along the chain. This observation was confirmed along the cold logistics chain.

Another significant barrier relates to the influence of strategic sourcing alliance along the red meat supply chain—the role of the stock agent influences this barrier**. In this barrier, t**he research found that the limited interaction to NLIS and the poor technology literacy observed in the farm production phase of the chain could be linked to the increased reliance on the third-party actor, i.e. the stock agent, who acts on behalf of farmers in the registration of animal tags and transaction notification after-sales. Previous studies have raised the issue of ICT literacy as a significant factor impacting IT use and adoption amongst many small businesses (Harindranath et al., 2008). Most ICT literacy research focuses on the challenges related to the inability to use basic IT tools and systems to gather organize, analyse, and report information using (Leu Jr et al., 2000).In Australia, challenges related to critical issues such as skills shortage have been suggested in a report developed by the Australian Department of Industry & Science[46]. While this study agrees with the view that skill shortage and limited educational attainment could be responsible for poor ICT literacy amongst small businesses, there is evidence to suggests that the stock agent may be contributing to this poor ICT literacy particularly in terms of digital engagement with the NLIS system, thereby leaving the farmers to limited interaction with the system.

Secondly, in terms of supply chain structure, the key issues were found to include barriers such as **poor scheduling and supply chain coordination,** fragmentation of the chain and traceability approach, (i.e. limited to OUOD); and power distance between the meat processor and the retailer**.** Amongst these factors listed, the research found that fragmentation of information and power distance between the butcher and the meat processor was the most significant contributors to limited traceability along the red meat supply chain. In previous studies (Romero et al. 2013; Schuetze et al. 2017), issues of poor scheduling and supply chain coordination have been identified as significant barriers to IT traceability in food supply chains**.** These studies found that because small businesses tend to operate independently, they are challenged by the lack of coordination and inability to support specialised supply chain management functions such as planning and control (Katunzi et al. 2010), and consequently impacts the performance of traceability in the chain. This study observes a similar relationship between supply chain co-ordination and poor traceability performance. In this study, key observations in the supply chain showed that the pre-slaughter segment, i.e. between the farmer, transport, and saleyard

[46] http://limestonecoastredmeat.com.au/wp-content/uploads/2015/11/AusIndustry-mapping-report-public-version.pdf

operations, were most vulnerable to the issue of poor co-ordination along the chain. However, this study also poor organisational attitude and lack of interests were found to be the prevailing challenges facing Tasmanian businesses in implementing IT to support traceability and for responding to some of the most critical challenges faced in the chain.

In terms of fragmentation, the research confirmed that information sharing between supply chain partners are siloed at the meat processor, and it is difficult to follow the origin of the meat back to the farm. Most studies acknowledge that supply chain fragmentation remains a critical issue for Australian beef industry supply chains and poses significant risks to the performance of the chains [47]. This study further confirms that issues of fragmentation remain a crucial barrier to the effective implementation of new IT for supporting traceability along the red meat supply chain. For example, amongst some retail butcher, information is siloed at the meat processor, and this affects the butcher's ability to obtain complete details related needed to support enhanced traceability and possibility value-adding to the meat product.

The issue of power distance was observed to be another significant contributor to poor IT traceability amongst small businesses. Power distance refers to the relationship between those in power and the subordinates within a supply chain. In this study, the research found poor traceability performance between the retail butcher and the meat processor was because of the limited influence the butchers' posses over the larger businesses (i.e. meat processors), most of whom operate in both the domestic and export markets and less accountable to smaller businesses. In this context, the supply chain relationship between the butcher and meat processor is found to be transactional rather than collaborative to support the whole of chain traceability for the red meat purchased. These findings related to power distance can be further explained using the theoretical underpinnings of transaction cost economics (TCE){Stranieri, 2017 #18}. TCE assumes that economic actors are affected by bounded rationality and opportunism and that, because of these constraints, they cannot predict in advance all possible contingencies surrounding a transaction {Stranieri, 2017 #18}. In this context, transaction governance such as

[47] https://www.ampc.com.au/uploads/cgblog/id65/42161_AMPC_RiskDocumentvLR.pdf

compliance to traceability standards, are not only viewed as a tool to reduce transaction costs but also as a tool to manage transaction risks{Wever, 2012 #19}.In this study, the research finds that existing traceability standards developed and implemented in the chain may be contributing to the lack of incentive to enhance existing traceability standards as long as they meet minimum requirements. However, for the small businesses with very limited means of verifying the information beyond what is provided to them, they are exposed to multiple risks and challenges of authenticity and as a result are unable to ascertain whether the traceability information provided by the suppliers concerning is complete, misleading or in compliance with the conditions of existing transaction arrangements.

In terms of traceability approach, the research found that many of the small businesses interviewed were not inclined to improve their traceability because of perceived lower cost, limited regulatory requirements and ease of operation of existing paper-based practices. In previous studies (Karlsen et al. 2016), similar findings have been suggested that amongst small businesses, many prefer to utilise OUOD traceability because of the lower-risks involved in disrupting existing production process, the minimal cost of implementation and maintenance, ease cooperation, and less stringent requirements for controlling production processes. This study further corroborates these findings from the authors and confirms these factors as significantly affecting the improvement of traceability along the red meat supply chains using low-cost technologies.

10.4.5 PRE-INTERVENTION-BASELINE DATA COLLECTION

10.4.5.1 APPLICATION OF THE HEURISTICS FRAMEWORK IN THE MULTIPLE CASE STUDIES

The use of the heuristic framework revealed several key findings, including the fact that there were various information quality challenges impacting visibility and traceability along the red meat supply chains., particularly with the retail butcher. Metrics for understanding how to improve traceability and supply chain visibility in supply chains have been widely researched in the literature (Zhou 2009). Wang et al., (1998), for example, suggested four IQ dimensions, namely: intrinsic IQ, contextual IQ, representational IQ, and accessibility. Golan et al., (2004) and McEntire et al. (2010) also suggested the use of information quality using metrics such as the breadth', 'depth', 'access' and 'precision'. Molnár et al. (2011) also suggested 9 information quality challenges impacting transparency and traceability in food supply chains, and these include *accuracy, relevance, timeliness, reliability, completeness, usefulness, credibility, trustworthiness and being up to date.* In this study, the research identified 4 significant information quality metrics underpinning potential challenges along the chain, and these include *format, accuracy, completeness (accessibility), timeliness (freshness and currency) and precision.* In the framework developed by Caridi et al. (2010) for measuring visibility to traceability challenges, only 3 metrics were utilised. This study adds a new dimension of information quality metrics, called format, which relates to the degree to which traceability information is whole paper-based or fully electronic.

In the baseline data collection step, there were markedly different perceptions amongst supply chain participants concerning their perceived level of visibility to potential traceability challenges faced both within individual firms and also along the supply chain. For example, in some cases, the participant saw their level of visibility to be much higher than observed in the field by the research, and thus raised the issue of verifiability of visibility assessment. The problem of verifiability in the subjective evaluation of information quality assessment is not new (Naumann et al., 2005). However, a significant consequence for the researcher is that when assessment criteria cannot be verified, it diminishes confidence in the quantitative score obtained and the accuracy of the result. Although the information user(e.g.. farmer) must be the candidate to assess information quality criteria (Knight et al., 2005), however, the research finds that there is a need for the use of an expert assessor(investigator) to provide counter-assessment to enhance accuracy, reliability, and verifiability of results used in the baseline assessment along the chain. In responding to this challenge, the researcher consulted with the participants individually to discuss the key challenges observed during the field visit based on field assessment and this was also taken into consideration in arriving at specific areas of intervention on traceability the farm.

10.4.6 TECHNOLOGY INTERVENTION

10.4.6.1 THE NEW ROLES OF IT ON TRACEABILITY AMONGST SMALL BUSINESSES IN RED MEAD MEAT SUPPLY CHAINS

The research identified new roles that low-cost mobile technologies can play in traceability for responding to some of the most critical challenges faced along the red meat supply chains. **In the area of animal welfare**, the research deployed an Ovi-Bovi® cow monitoring system to support visibility and for responding to traceability challenges of animal welfare in the farm production stage of the chain. The animal monitoring system is widely utilised to help several new roles in traceability in the area of animal welfare including (a) to support the ability to track the movement of cattle both in the farm, during transportation an prior to slaughter to improve early detection of heat, illness, stress, or temperament (González et al. 2008); (b) measure vibration levels of trucks and to optimise handling procedures during transportation of cattle and sheep(Aradom 2012), and monitor behavioural and positioning level of beef cattle as a way of detecting illness or changes in activity patterns (Tullo et al. 2016).

In this study, the research found that the mobile sensing device deployed in the farm played new roles in traceability in terms of enhancing visibility to *animal behavioural in the farm through the measurement of welfare parameters such as* Activity, Lying, Tilting, and Feeding behaviours. However, the mobile technology intervention deployed on the farm and on the animals also revealed several new difficulties that could negatively impact the successful implementation and utilisation of the system in the system. These include *animal temperament, internet connectivity, geographical terrain, and grazing approach. Amongst these issues identified, the research found that* the geographical terrain poses the most significant challenge to the successful deployment of the system on the farm. A similar finding conducted by Kamminga et al. (2018) also reported similar findings. In their report, the authors reported the performance of cow activity monitoring system could be significantly affected by the geographical terrain of the farm and consequently limit the useability of the system in the field in some cases. In terms of animal temperament, another study by Radenkovic et al. (2006) reported similar performance-related problems associated with the use of activity collars on cows. The authors found that sensors devices could cause excessive annoyance on the cattle if improperly placed and this could impact negatively on the performance of the tag. This study confirmed that these external factors could have a significant impact on the useability of the sensors on the cattle.

In the area of meat safety, the research deployed 2 low-cost wireless sensor network in 3 different points of the red meat supply chain, namely the meat processor, cold chain, and retail butcher. In the meat processor, the research deployed a Bluetooth ® wireless temperature monitoring system in the cold room to improve visibility in meat temperature condition of the abattoir. The wireless sensors played new roles in the traceability of meat safety in terms of temperature monitoring. The technical data generated provides substantial evidence of irregular refrigerating performance and possible temperature abuse (indicated by greater than 5oC threshold) in the abattoir. However, no indication of temperature abuse was evident through the temperature profile generated for each chilling equipment monitored.

In the cold logistic chain intervention, the research deployed an NFC temperature tracking system to verify compliance to meat temperature condition during road transport. The technology intervention played new roles in traceability in the area of cold chain monitoring and enhanced visibility of operations. The technical data generated from the sensor intervention revealed a relatively stable temperature condition below the maximum threshold of 5oC. This further shows that the refrigerating equipment in the truck was operating at optimal performance during road transportation. In the retail butcher, the research deployed 2 wireless sensor monitoring system to improve visibility and remote monitoring of cold room within the butcher store. Overall, the temperature information captured through the sensors indicated average equipment chilling performance based on the number of peaks above the maximum threshold. However, no indication of temperature abuse was evident through the temperature profile generated for each chilling equipment monitored during the intervention period.

In the area of meat provenance, the research deployed 2 low-cost mobile technology at two different points along the red meat supply chain, and these include the meat processor and meat provenance. In the meat processor, the research deployed a carcase labelling system which played a role in identity preservation. The experiment also demonstrated the feasibility of implementing the low-cost barcode labelling solution in the abattoir with limited training and low-cost of implementation and maintenance. However, during the experiment, the farmer did not provide an RFID tag number for the lambs, which could have enhanced traceability from a whole of life perspective by integrating RFID tags with the generated barcode in the abattoir. Furthermore, this incident occurred during the experiment confirms the belief held by one industry stakeholder concerning issues of lost traceability facing meat processors. On further examination and follow-up, the research found the farmer did not see the value and importance of providing RFID tags information since the sheep were processed and transferred directly to the butcher. This incident meant that the experiment was unable to link RFID tag identification with barcode labels on individual meat carcase. It also shows that without co-operation and digital participation amongst actors, implementing full traceability in the lamb chain remains a major challenge for most small business owners.

In the butcher store, the technology intervention played new roles in traceability in areas of meat verification (i.e. origin) and authentication (using mobile devices and QR code). However, the research also observed a marked difference amongst the case studies in terms of customer interest in the utilisation of the mobile. This observation is solely based on app download statistics obtained from Android and iOS platforms. For example in case study 2, with customers using Android devices there were 17 total unique downloads of the mobile app on the google play store as compared to 0 customers who visited the iOS store to download the app. This indicates that the consumers with Android phone were more interested in the meat provenance than those customers with iOS devices. The research could not find any study with similar findings. It could also suggest that the butcher store has more Android-based customers that were interested in meat provenance than iOS-based customers. Overall the findings from the intervention, while minimal in scope, shows that consumer interests were enhanced particularly amongst those with Android devices as compared to those using iOS devices. In case study 3, only 6 customers installed the mobile application from the Android platform, indicating some level of consumer interest amongst consumers with android mobile phones. However, no consumer with iOS devices downloaded the app. This finding may suggest that customers with iOS devices were not interested in verifying information on meat origin. It could also be that no consumer with iOS device visited the store during the intervention. In terms of the number of QR code scans, a total of 8 unique scans were captured. Although a relatively low number, it indicates that some consumers were interested in the traceability of lamb when visiting the butcher store. In case study 4, no customer downloaded the app nor scanned the QR code to access information of beef provenance. This lack of technology interaction indicated the lack of consumer interest amongst visiting consumers in learning more about the origins of their meat. However, these findings also confirm the belief held by the retail butcher who mentioned that most of the clients that visit the store to purchase red meat are interested in a face to face interaction rather than using a mobile app to inquire about more information on a meat product. This is in contrast to other studies that have reported significantly higher levels of consumer interest on red meat traceability (Verbeke et al., 2006).

10.4.7 POST-INTERVENTION EVALUATION

10.4.7.1 THE POTENTIAL IMPACT OF THE LOW-COST MOBILE TECHNOLOGY INTERVENTION ON TRACEABILITY

There were marked differences in the perceived impacts of low-cost mobile technology on traceability amongst the small businesses at different points along the red meat supply chain. Some participants perceived a positive impact of the technology intervention on traceability, while others felt a negative or no impact of the intervention on traceability along the chain. However, these impacts can be categories into two broad categories, namely *organisational operations and information quality.* **In the farm production phase,** the technology intervention improved the level of visibility to traceability challenges along different points of the red meat chain in the following areas, namely a*ccessibility, timeliness and accuracy, and format*. However, the participant did not perceive any of these impacts on information quality and enhanced visibility to animal welfare. However, there were also negative impacts. For example, the research found that the technology intervention negatively impacted the perception of the farmer concerning the role and potential impact of the low-cost cow activity monitors on traceability. For example, in terms of information quality and visibility, the farmers' opinion was that enhancing the currency and freshness of information, i.e. timeliness, would hurt daily business operations due to information overload. The farmer concluded that constant information monitoring and alerts received from the sensors were a distraction rather than a benefit to the business. This feedback received from the farmer showed that he struggled to see the value and benefit of the technology intervention in the farm despite the enhanced visibility provided as compared to existing practices of visual monitoring using face to face interaction with the animals. However, in contrast to these findings, some studies (Van Vliet et al., 1996, Arcidiacono et al., 2017) have found a positive impact from having deployed cow activity monitoring systems to support traceability in the area of animal welfare on the farm.

In the meat processor phase, the technology intervention enhanced the amount and quality of information on meat provenance and meat safety in the following areas, namely in terms of *format, accessibility, accuracy,* and *currency and freshness*. However, this observation is in contrast with the feedback received from the participant who stated that the sensor intervention did not play any significant role or impact on traceability. The research found that the participant did not utilise the mobile app during the experiment, suggesting a lack of interests, *and negative attitude towards* the sensor technologies. In the area of meat provenance, the participant at the meat processor did perceive a new role for enhanced carcase identification and its potential impact in responding to growing consumer *awareness and demands* for product traceability. However, no significant impact of the carcase labelling system deployed was perceived by the participant in the abattoir, partly due to the perceived limited scope and size of processing operations. The participant also believed the size and scope of business operation could not justify investment in a labelling system. This belief can be inferred to be as a result of *limited value proposition* concerning the use of barcode labelling system as compared to the use of tattoo ink. These findings are in stark contrast to other research studies that have reported a positive attitude amongst small businesses towards traceability due to *perceived usefulness of IT traceability in* areas of recall, compliance and consumer assurance. (Mattevi et al., 2016b).In **the cold chain phase,** the technology intervention impacted traceability in the area of temperature visibility between the meat processor and the retail butcher., the information quality metrics most impacted by the cold chain intervention includes *accuracy, accessibility of information but not the timeliness*. However, the participant did not perceive this impact and perhaps not surprising why the participant's feedback concerning the cold chain intervention indicated a "no impact".

In the **retail butcher phase,** there was the markedly different impact of the mobile technology intervention deployed in the store to support traceability of red meat (i.e .meat provenance, meat safety, and meat quality). For example, in case study 2 (butcher 1) the research found that the low-cost mobile technologies impacted positively on traceability in relation to meat safety in two areas, namely: (a)

Information quality- in terms of *accessibility, format, accuracy, freshness and currency, and completeness of information;* and (b) *organisational behaviour*- the sensor played a role in *detecting and correct staff behaviours during cold store operations*. The technology also enhanced organisational awareness and responsiveness to potential risks of meat spoilage, equipment failure, and scheduling maintenance of the fridges. These findings are similar to other studies that show the positive impact of IT on traceability amongst small businesses (Sahin,2002). However, the research also found that **in the meat provenance intervention**, the mobile app played new roles in positively impacting traceability in areas that *product marketing and branding, enhanced customer service and consumer awareness*. A similar positive impact of IT in traceability has been reported in a retail food business (Jones et al., 2005), where the authors mentioned that introduction of new mobile technologies could enhance customer service and improve management and control of organisational operations.

In terms of branding and marketing, the research found that the mobile verification app provided new means for the retail butcher to add value to the lamb and beef meat sold to consumers and could be seen as enhancing the reputation of the retail business. In terms of consumer awareness, the web analytics data obtained from the mobile app intervention revealed substantive consumer interest and willingness amongst **In case study 3 (butcher 2),** the feedback received from the participant at the meat processor and retail butcher indicated that the technology intervention had both positive and no impact of traceability in areas of provenance and meat safety. Positively, the technology intervention impacted *information quality* and *organisational operations within the butcher store.* **In term of** information quality, the research found that the meat provenance app enhanced *accessibility and currency and freshness of information.* In terms of organisational operations, the study found that the technology intervention raised consumer awareness and consumer assurance regarding the provenance of the lambs.

In case study 4 (butcher 3), the feedback received from the participant revealed markedly different findings in the role and impact of technology in both interventions, i.e. meat safety and meat provenance. In terms of meat safety, the research found that the intervention played a new role in positively impacting traceability in two key areas, namely: *information quality and organisational attitude*. In terms of information quality, the research found that the sensor intervention enhanced accessibility, *freshness and currency, reliability, format* and *accuracy of temperature information.* In terms of organisational attitude, the research found that the sensor intervention impacted the butcher's perception concerning the need for new technologies in enhancing traceability in the store. For example, the participant believed that the sensor intervention could enhance the *organisational responsiveness to* temperature abuse and potential meat safety breaches in the store. **In the meat provenance intervention,** the technology-enhanced the quality of traceability information on meat provenance in terms of the *accessibility, format, currency and freshness*. However, the intervention did not have any positive role or impact on the organisation due to lack of consumer interests. In reflecting on case study intervention, the research found that *technology portability and consumer interests are the* two critical factors that could play a new role in positively impacting traceability, and also in the successful utilisation and potential adoption of the mobile technologies in the butcher store. Findings ways to enhance consumer interest in utilising an app to learn more about their meat would mean a better understanding of customer interests and to ascertain the information cues of value and importance to their purchasing decisions.

10.4.7.2 EXTERNAL SOCIO-TECHNICAL FACTORS LIMITING THE ROLE AND IMPACT OF IT ON TRACEABILITY AMONGST SMALL BUSINESSES

There were new external socio-technical factors that limited the successful deployment and utilisation of low-cost mobile technologies along different parts of the chain for supporting traceability and responding to some of the critical challenges face. Furthermore, these factors were observed to markedly different at the different segment of the red meat supply chain from the farm production phase to retail. In the farm production phase, the external socio-technical factors include *commercial viability, technology usefulness and suitability, business size and organisational objectives/value proposition.* On closer analysis, the three key factors appear to align with the theoretical constructs underpinning Technology Acceptance Models(Dulle et al., 2011) and the Unified Theory of Acceptance and Use of Technology (UTAUT)(Ahmad, 2015). **Firstly,** the research found that the category "*perceived commercial viability" is linked to performance expectancy (TAM), i.e.,* the degree to which an individual believes that using the system will help him or her to attain gains in job performance. **Secondly,** the category "*value proposition"* can be linked to perceived usefulness (TAM), i.e., the prospective user's subjective probability that using a specific application system will increase his or her job performance within an organisational context. **Thirdly**, the category *business size* can be linked to job fit (TAM) –—the extent to which an individual believes that using [a technology] can enhance the performance of his or her job. **Fourthly,** in terms of performance expectancy (TAM), the research found a link with *the lack of consistent internet* – that is the expectation that the system should provide information that is timely and accurate on animal behaviour and wellbeing. It is possible that the participant provided these feedback based on the future potential use and adoption of the system rather than an assessment of its utility during the field experiment. However, the research also found that these technology adoption factors may have contributed to the perceived *lack of perceived usefulness and acceptance* of the cow-activity monitoring technology on the farm, and perhaps even the negative feedback obtained from the participant during the post-intervention and evaluation phase of the study.

Kolshus K (2015) suggested 7 factors that contributed to or could potentially inhibit the successful utilisation and adoption of new technologies amongst small farmers. These factors include : (a) diversity (difficult and limited access for women, older and poor farmers, and people living in remote areas); (d)Access and participation (gender-based and rural-urban digital divides persist); (e) Partnerships (few and mostly ineffective public-private partnerships); (f)Technologies (the challenge of identifying the right technologies mix that is suitable to local contexts); (g) Economic, Social and Environmental sustainability (difficult scaling up of pilot ICT projects and initiatives). In this study, only three factors were identified in relation to the cow-activity monitoring system deployed, and these are *organisational characteristics and external environmental factors and technology adaptation*. Organisational characteristics relate to the nature and type of business operations being supported in the farm, e.g. hubby farmer, part-time business etc. External environmental factors are those external factors that exist beyond the control of the butcher and have the potential to limit successful utilisation of the cow-activity monitors. In this study, the most significant environmental factors were internet connectivity, geographical terrain, and grazing approach. Technology adaptation relates to the feasibility of the deployment of the technology on animals. Furthermore, in deploying the collar band, the research found that some animals were uneasy during the experiment and this accounted for cases of lost tags.it is also possible that the difference in temperament and inconvenience may have contributed to the inability to successfully collect data from one of the sensors.

In the meat processor phase, 2 external socio-technical factors were identified as being significant to the utilisation and potential adoption of the low-cost technologies deployed in the abattoir, and these are: (a) perceived cost of technology acquisition; (b) implementation and maintenance, and limited value proposition. In terms of the perceived cost of acquisition, the research found that the participant in the meat processor believed that new ICT to support internal traceability was expensive to implement and the existing business structures (i.e. sole trader) could not justify new investment in ICT. This perception is as a result of the limited awareness of modern traceability technologies available for meat processors to improve traceability within their business. The issue of implementation and maintenance cost and limited value proposition are linked to each other because of the perception with the meat processor that many of the technologies available and utilised in the abattoir were increasingly expensive to maintain and were not value adding to the business. In particular, the perceived *low volume of transactions, poor attitude and behaviour, and lack of owner interest were also found to contribute to poor perception.* These perceptions held by the meat processor are not new. In previous studies, it has also been recorded by authors in terms of the factors that significant impact of small business capacity to utilise and adopt new ICT (Vaaland and Heide, 2007). These factors include issues of resource limitations, structures of the supply chain in which they operate, lack of familiarity with the technology and its benefits, lack of technology prioritisation. Previous studies (Kelepouris et al. 2007; Mattevi et al. 2016a), have also reported similar findings concerning significant barrier impacting IT use and adoption amongst small businesses in red meat supply chains.

However, 2 new barriers the TAM (Dulle et al., 2011) were discovered to be playing a significant role in limiting IT utilisation and adoption in the meat processor. They include *perceived usefulness*, and *intention to adopt*. Perceived usefulness refers to the extent to which the participant believes that technology intervention will enhance organisational traceability performance(Theuvsen et al., 2005). *Intention to adopt* refers to the degree to which the participant anticipates investments in the system either in current circumstances or later in the future(Horst et al., 2007).

In the retail butcher store, 5 barriers to the successful deployment and utilisation of low-cost mobile technologies to support traceability were identified. In the area of meat provenance these include: (a) *strong consumer incentive, location of technology deployment, lack of consumer interest); (b) and meat safety criteria (technology portability* and *ease of use).* **Firstly, in terms of developing strong consumer incentive,** the research found that providing traceability information on the origin of the meat product is not enough to stimulate consumer acceptance and utilisation of the mobile app technology. There is a need to understand and align consumer interests with important information cues to stimulate digital acceptance of the technology for verification and engagement with the meat labels. This strong consumer incentive has been defined elsewhere as understanding the end-use proposition for new technologies in businesses (Goldsmith, 2004). **Secondly, in terms of the *location of technology intervention*.** The research found that deployment the QR code verification system in the store enabled the butcher to more easily communicate the importance of the app during pre and post-purchase interaction to the consumer. It is believed that consumers are less likely to scan the QR code at home because they might not utilise the app once they leave the store. The research did not find any literature that has reported this new finding from this study. Furthermore, the research found that consumers are more likely to buy their meat and leave the store without checking the provenance if the technology were to be deployed on the packaging of the meat rather than as a poster in the store. Thus, to enhance digital participation with consumers, the butcher believed that the best location would be to deploy the QR code in the store rather than on the meat label. **Thirdly, the *lack of consumer interest*** refers to the strong preference amongst retail meat butcher consumers to verify information about a meat product through face to face interactions rather than using the mobile app. These findings are in contrast to other studies Verbeke et al. (2006), that have reported significantly higher levels of consumer interest on red meat traceability using the mobile app. In this research, the retail butcher mentioned that the lack of consumer use of the app (see case study 4) is likely to be due to strong preference for direct face-to-face interactions during pre-purchase rather than using a mobile app.

In term of meat safety intervention, the research found that *technology portability* and *ease of use* are the most critical success factors that could support the future utilisation of the mobile wireless temperature sensor network system in the butcher store. These two factors further confirm previous studies (Jones et al. 2011; Widyastuti et al. 2018), that suggest both as important determinants underpinning the successful use and potential adoption of mobile technologies in small businesses. Technology portability relates to the extent to which the technology can be easily carried or moved within the store and also out of the store. The wireless sensors provided a cloud-based monitoring system which allowed the butcher to assess information related to meat temperature in the butcher store over an internet connection. Ease of use refers to the extent to which the wireless sensors technology was easy to be navigated and the degree to which the data generated could be analysed and interpreted easily. In this study, the sensor network provides integrated into a mobile app provided full temperature charts with green and red lines that allowed the butcher to assess the level of risks related to meat temperature and refrigerating performance of the equipment in the store. These two factors are widely regarded as important determinants which underpin the successful use and potential adoption of mobile technologies in small businesses(Jones et al., 2011, Widyastuti et al., 2018).

10.4.8 REFLECTION ON THE PROPOSED HEURISTICS FRAMEWORK

In reflecting on the heuristic framework, some key findings have emerged. Firstly, the research found that the framework is helpful for quantifying visibility levels in fragmented supply chains, and can also serve as a proxy for understanding how and where to improve information quality in order to enhance traceability. However, in conducting the assessment, the research also found the use of subjective judgment of the information user to be erroneous and incapable of assisting in the identification and selection of critical areas for technology intervention. Although, the authors of the visibility assessment framework did raise some concerns about the potential for bias in judgement from the information users(Caridi et al. 2010; Caridi et al. 2013).This research finds this caution to be very significant in this adapted framework and could limit the utility and reliability of results obtained of the framework.

Secondly, the framework did not take into consideration the *format* dimensions of information quality which was significant in this study, i.e. degree to which information is fully paper-based or fully electronic. In traceability amongst small business owners, many still utilise paper-based approaches. The research finds that the transformation of traceability information from one format (i.e. paper-based) to another (i.e. semi-digital or fully digital) amounted to some level of visibility improvement and should be considered an important information quality criteria in evaluating the potential impact of IT on traceability amongst small businesses operating in the red meat supply chain.

Thirdly, the research found that some participants declined to use the self-assessment tool due to the perception of being evaluated as poorly performing in areas of information quality and the possibility of being assessed negatively. This is the case of the **meat processor** in the lamb supply chain in case study 3. The participant was willing to experiment with new technologies but not interested in visibility assessment. Fourthly, the research was faced with some difficulties in assessing a firm's total visibility to traceability challenges (i.e. provenance, meat safety, meat quality, and animal welfare) along the supply chain. This difficulty is due to the fragmentation of information, and as a result, only a node partial visibility of information in relation to potential traceability challenges faced could be conducted rather than total visibility of information. This is also because small business owners prioritised traceability information differently both in their businesses and also along the chain due to varying business objectives. In this context, the research suggests that the heuristics framework be converted to a node partial visibility assessment methodology, and the key information of critical concerns are prioritised based on organisational need.

Despite some of the drawbacks observed during the application of the heuristics framework, there were some important benefits as well. For example, one key benefit is that it provides the researcher with a new lens to understand how small business owners perceive their level of visibility, and what factors are considered in evaluating information quality aligned to traceability information and challenges faced. Based on these key findings, the research proposes an alternative small business traceability framework for understanding how and where low-cost mobile technologies can be most effectively deployed to play new roles in impacting traceability along the red meat supply chains at different points. The next section describes the key components of the framework.

10.5 CROSS-CASE INTERPRETATION, DISCUSSION AND SUMMARY OF FINDINGS

This research explored traceability challenges amongst small businesses along the Tasmanian red meat supply chain. The purpose of this exploratory study is to understand the role and potential impact that specific low-cost mobile technologies can have on traceability both within individual firms and along the supply chains. To guide the conduct of this exploratory study, the research utilised a three-phased strategy that comprises of pre-intervention; technology intervention, and post-intervention and evaluation. **In Phase 1 (pre-intervention -industry familiarisation step 1)** the interactions with 7 industry and government stakeholders generated a list of some of the potential traceability challenges impacting Tasmanian small businesses along the red meat supply chain. These challenges were found to be related to meat *provenance, meat safety, meat quality/authenticity, and animal welfare*. The interaction with the industry and government stakeholders also revealed some important socio-technical challenges that impact Tasmanian small businesses in their traceability along the red meat supply chain. These include issues of poor digital literacy, poor internet connectivity, lack of awareness, organisational attitude and behaviour. These factors underpin some of the critical vulnerabilities that expose small businesses to potential traceability challenges and risks in their supply chains.

In Phase 1(Pre-intervention-supply chain mapping step 2), 11 participants were recruited from different segments of the red meat supply chain to understand whether these traceability challenges do impact Tasmanian small business owners in their supply chains. The research was able to confirm many of the challenges identified in step 1. In terms of meat provenance, these issues relate to *identity preservation (meat labelling), proof (verification) of meat origin, transparency, meat quality (branding and marketing), and animal welfare (poor scheduling)*. In terms of meat safety, key issues related to *lack of visibility to meat temperature* in the meat processor, cold logistics chain, and in the retail butcher store. In terms of animal welfare, the key issues are related to *poor visibility to animal wellbeing and behavioural* patterns. The traceability challenges related to meat quality/authenticity were related to *product marketing and branding*.

In the baseline data collection, 4 small business owners agreed to participate in visibility assessment to measure how they perceive their level of traceability to information related to the challenges faced. Amongst the case studies, all participants except for the retail butcher in case study 3, perceived a high level of visibility to information aligned to the meat product in the chain. This bias in assessment impacted negatively in the reliability of the questionnaire.

In the technology phase, the research deployed some low-cost mobile technologies at different segments of the supply chain. These technologies include cow-activity monitoring system, mobile meat verification app, portable temperature monitoring system, and wireless sensor network for temperature monitoring. Table 21 below shows the technologies deployed in the four case studies explored in this study. These technologies play different roles in traceability as follows:

- **In case study 1,** the technology intervention played a new role in traceability in the *animal behavioural monitoring*. However, the intervention also revealed some external factors that could negatively impact the successful implementation of the system, and these include *animal temperament, internet connectivity, geographical terrain, and grazing approach.*

Table 21: Role and potential impact of low-cost mobile intervention of traceability and organisational practices

Case study	*Technologies deployed*	*Role of IT*	*Impact on traceability (Information quality criteria)*	*Impact on organisation practices (organisational criteria)*
Case study 1 (Farmer)	Ovi-Bovi ®Cow activity monitoring system	Animal behavior monitoring-	**Accessibility, format**	**Negative impact on value proposition**
Case study 2 (Butcher)	Meat verification app /QR code	Proof of origin, marketing and branding	**Accessibility, currency/freshness**	**Consumer awareness**
	SensorPush®Temperature sensor network	Monitoring and notification	**Accessibility, currency/freshness, accuracy Format**	**Organizational Awareness, correcting staff behavior, Willingness to adopt**
Case study 3 (lamb supply chain) Meat processor	Barcode Labelling	Labelling/ Identity preservation	**Format, Accessibility,**	**No Impact**
	SensorPush® Bluetooth wireless temperature sensors	Monitoring and notification	**Accessibility, currency/freshness, accuracy Format**	**No Impact**
Cold chain	Blulog® Portable NFC temperature tracking	Cold chain verification	**Accessibility, currency/freshness, accuracy Format**	**Organisational awareness**
Retail butcher	Meat verification app/QR code	Proof of origin Consumer assurance	**Accessibility, currency/freshness, accuracy Format**	**Consumer interests**
Case study 4 (Retail Butcher)	Meat verification app/QR code -	Proof of origin	**Accessibility, currency/freshness, format**	**No Impact**
	SensorPush® Temperature sensor network	Monitoring and notification Meat safety risk detection	**Accessibility, currency/freshness, accuracy Format**	**Organisational responsiveness**

- **In case study 2**, the technology intervention played two new roles in traceability in areas of meat safety and meat provenance. In terms of meat safety, the technology intervention played new roles in temperature monitoring and notification of abuse. In terms of meat provenance, the technology played new roles in traceability in terms of enhancing product marketing and branding in the butcher store.
- **In case study 3,** the research deployed 4 low-cost technologies to play new roles in traceability at different points in a lamb chain in the following areas: (a) **Meat processor –** in the area of provenance, the barcode labelling system played new roles in traceability in identity preservation. In the area of meat safety, the technology played new roles in temperature monitoring. (b)**Transport-** in terms of meat safety, the sensor intervention played a new role in traceability for transparency of operations and cold chain verification
 (c) **Retail butcher-** in terms of meat provenance, the technology intervention played a new role in consumer assurance and meat verification.
- **In case study 4**, two low-cost technologies were deployed in the butcher store to play new roles in traceability in the following areas: meat provenance-proof of origin, and meat safety-*temperature monitoring and notification of abuse.*

In the post-intervention and evaluation phase, the research found markedly difference in perceived role and impact of the technology intervention on traceability and organisational operations. The summary of the response is shown in Table 21 above. The key summary is as follows:

- **In case study 1,** the technology intervention impacted positively on traceability in terms of improvement in information quality (accessibility and format), and negatively in terms of the organisational value proposition. The participant did struggle to see the value of the cow-activity system and held a negative opinion after the intervention. This was in contrast to the pre-intervention, where the participant was enthusiastic about experimenting with the technologies to see the opportunities it can offer.
- **In case study 2,** the technology intervention impacted positively on traceability in enhancing information quality (accuracy, accessibility, currency and freshness, format), and positively in organisational practices in

areas of enhancing organisational awareness and correction of staff behaviour, fault detection of the refrigerating equipments in the store, marketing and business branding.

- **In case study 3,** the technology interventions impacted traceability positively in terms of improving information quality in the following segments (a) **Meat processor(**accessibility, freshness and currency, and format); (b)**Cold chain** (accessibility, format, and accuracy); (c) and **retail butcher** (accessibility, format, freshness and currency). However, within individual firms, the technology intervention revealed no impact at the meat processor and retail, and slightly moderate impact in the butcher in terms of enhancing consumer awareness and assurance on the authenticity of the meat positive, negative and no impact.
- **In case study 4,** the technology interventions within the butcher store had a revealed positive on traceability and organisational practice. In terms of meat provenance, the technology intervention impacted positively in traceability in enhancing information in terms of format and accessibility. However, no organisational impact was perceived or observed due to lack of consumer interest. In terms of meat safety, the technology intervention impacted positively on traceability, and positively in organisational awareness and responsiveness to meat risks.

In reflecting on the heuristics framework utilised in this study, the research identified a number of new key findings. Firstly, the research found that while the 3 information criteria adapted from the work of (Caridi et al., 2010)(i.e. accessibility, accuracy, and currency and freshness) was helpful, it did not provide sufficient understanding on the range of information quality challenges impacting traceability amongst the small business owners in the chain. Of particular importance is the information quality criteria "*format*", which was found to be very significant. Secondly, the research observed some bias in judgement amongst small businesses involved with assessing current visibility levels to traceability information, and the potential challenges faced in the chain, suggesting the need for external assessor. In interpreting these visibility scores, the research found that observed visibility levels to the traceability challenges by the researcher were lower than the perceived visibility levels scored by the supply chain actors. This differences is perceived visibility levels impacted the utility of the framework. Thirdly, the heuristics framework was limited in application to node visibility assessment at a node rather total visibility assessment as initially suggested in this study. The research found that total visibility assessment was impractical for assessing visibility amongst small businesses due to the limitation of the existing traceability practices, i.e. OUOD. In this context, visibility can only be assessed at nodes which can be called segments rather than an entire supply chain. Furthermore, some actors did not know the farm from where their meat came from and as a result, were unable to provide an accurate assessment of their traceability back to the farm. In such instances, provenance was limited to the meat processor and stock agent, which represented the contact point for most small businesses in retrieving information on origin aligned to a meat product.

In the post-evaluation phase, the research found that while some participants were interested in exploring options for potential adoption of the technologies moving forward in their business (i.e. case study 2), others were hesitant and did not see the value of the low-cost IT intervention. Based on the feedback received, it can be concluded that issues such as higher cost of implementation, limited training, lack of awareness, or complexity of deployment can no longer be cited as a barrier to lack of IT use and adoption to support traceability amongst red meat small businesses. This despite the fact that the research was able to illustrate to the businesses how some of these traceability challenges faced in the chain can be mitigated using low-cost sensor technologies, mobile app, and sensors deployed at different points of the red meat supply chains. There was also some level of training involved with implementing these technologies in the premises of the small business owners. The research found that the real challenges facing small businesses in this study were lack of perceived usefulness and value for new IT, poor organisational attitude, limited value proposition, and the problem of low digital participation amongst actors in the chain.

10.6 A NEW SMALL BUSINESS IT TRACEABILITY FRAMEWORK FOR SUPPORTING TRACEABILITY

Based on the findings from analysis and interpretation chapters, the research hereby proposes an alternative small business IT traceability framework for understanding how low cost IT can be deployed most effectively at different points along a fragmented red meat supply chain to enhance visibility in the information. Table 22 shows the proposed IT Traceability framework. The framework consists of 7 rows and 3 columns.

The first row is the supply chain segment. Here, the research proposes the use of 3 supply chain segments, and they are **pre-slaughter slaughter/cold chain**, and **retail/consumer.** Previous studies explore red meat supply chains as a single linear chain or as two distinct segments namely pre-slaughter and post-slaughter(Chulayo et al. 2012; Shanahan et al. 2009), without integrating the consumers. This study integrates the consumer into the chain and finds that amongst small businesses, the most practical approach for understanding and exploring traceability in a fragmented setting is to utilise a 3 segment strategy. This strategy takes into consideration the fact that many small businesses still utilise OUOD in their traceability and information sharing is limited to the immediate partners. Thus the three fragmented approaches allow for consideration of the limited traceability, i.e. product and information alignment, between small business owners along the supply chain.

The second row is critical traceability challenges. The research finds that amongst the range of potential traceability challenges impacting small businesses, the most critical is located in the following stages of the chain: Farm (Animal Welfare); slaughter/cold chain (labelling/cold chain), and retail (temperature monitoring, labelling/branding, authenticity, marketing and meat verification, consumer engagement). **The third row** is the traceable parameters. These are parameters or indicators that can be captured to enhance visibility and for responding to the critical challenges along the supply chains. In terms of animal welfare, significant challenges such as stress, illness detection, rumination behaviour, or heat-detection can be traced by monitoring animal movements. In the area of meat safety, the meat temperature is as an important parameter that is not adequately captured and readily accessible along the chain.

Table 22: Small businesses traceability framework for exploring traceability and deploying low-cost technologies

	Supply chain segment A (Preslaughter)	**Supply chain Segment B (Slaughter/Cold chain)**	**Supply chain Segment C (Retail)**
Focal firm(s)	Farm → Transport → Saleyard	Processor → Transport → Retail	Retail → Consumer
Critical Traceability challenges	Animal welfare	Cold chain monitoring and identity preservation	Verification of meat origin, and temperature monitoring
Traceable parameters	Cattle motion/Activity (3-axis accelerometer activity), GPS	Meat safety (Temperature); Meat Provenance (Barcode No, RFID Tag No).	Meat safety (Temperature); Provenance (geographical farm origin,QR Code labl);Meat quality (grade, animal breed, feed input, color), Animal welfare (Accreditation/)
Information quality criteria	Accessibility, accuracy, currency and freshness, (format)	Accessibility, accuracy, currency and freshness, (format)	Accessibility, accuracy, currency and freshness, (format)
Node Visibility Quality	Node_visibility_qualityk=√ Node_visibility_accuracyk * Node_visibility_freshness	Node_visibility_qualityk=√ Node_visibility_accuracyk * Node_visibility_freshness	Node_visibility_qualityk=√ Node_visibility_accuracyk * Node_visibility_freshness
Node Visibility Quantity	Node_partial_visibilityi,k= $\sqrt[3]{t_{c,s} * t_{a,s}\ t_{f,s}}$	Node_partial_visibilityi,k= $\sqrt[3]{t_{c,s} * t_{a,s}\ t_{f,s}}$	Node_partial_visibilityi,k= $\sqrt[3]{}$tc,s* ta,s tf,s
Node information (format)	Node_visibility_formatk= $t_{fo,s} * t_{fo,q} * t_{fo,p} * t_{fo,w}$	Node_visibility_freshnessk= tfo,s* tfo,q* $t_{fo,p} * t_{fo,w}$	Node_visibility_freshnessk= $t_{fo,s} * t_{fo,q} * t_{fo,p} * t_{fo,w}$
Suggested IT options	Ovi-Bovi Cow activity monitoring system	Barcode label/ChillVerify mobile app, Blulog®	Meat verification mobile + QR Code+ Web app,
Role of IT	Illness detection, heat detection, rumination behaviour	Identify preservation and cold chain verification	Authenticity, proof of origin, Marketing, Branding, consumer engagement

Table 23: Adjusted judgement scale of visibility metrics for traceability information at each supply chain node (adapted from Caridi et al. (2010)

Traceability information Freshness	Supply chain node (0)	I have access to none or less than 25% information (1)	I have access to at least between 25%-50% information (2)	I have access to at least 50- than 75% information (3)	I have access to at least than 75% or more information (4)
Traceability information Accuracy	Supply chain node	The accuracy of exchanged information is usually very low and unsatisfactory (1)	The accuracy of exchanged information is usually satisfactory but situations in which information is incorrect is not u common (2)	The accuracy of exchanged information is usually satisfactory which information in few situations (3)	The accuracy of exchanged information is usually satisfactory and very accurate (4)
Traceability information Completeness (Quantity)	Supply chain node	Information is not always updated and not satisfactory (1)	Information is only updated when I ask suppliers to provide data (2)	In some cases information is updated when the node is asked to provide data (3)	Information is updated in real time in most cases (4)
Traceability information Completeness (format)	Supply chain node	The format of exchanged information is manual or less than 25% digital (1)	The format of exchanged information is between 25% -50% digital (2)	The format of exchanged information 50%-75% digital (3)	The format of exchanged information greater than75% digital(4)

Other parameters included meat provenance, (geographical origin), meat quality/authenticity (feed input, colour, grade, breed). Participants can prioritise the parameters that are considered useful for their business operations. The fourth row is the information quality criteria, and they include accessibility, accuracy, freshness and currency, and format. The initial heuristics framework adapted (Caridi et al. 2010) utilised 3 information quality criteria, i.e. accessibility, accuracy, freshness and currency. However, the research finds that "information format" is a significant information quality criterion impacting visibility and capacity for traceability amongst small businesses in the red meat supply chain.

The fifth, sixth and seventh row describes the assessment formula used for measuring visibility to traceability challenges at each supply chain segment using these four information quality criteria, i.e. accessibility, currency and freshness, accuracy, and format. Table 23 above shows the adapted judgement scale of visibility metrics for traceability information at each supply chain node (adapted from Caridi et al. (2010). The judgement scale integrated information format into the questionnaire that is assessed separately at each node.

The eight row provides suggestions for some low-cost IT options based on those used in the study, and that can be implemented in similar red meat supply chains. These include the Ovi-Bovi Cow activity monitoring system, barcode label and chill verify, Blulog®, and the meat verification app and web app developed by the researcher. A new mobile app has also been developed to replace the portable temperature tracking sensor deployed in the study. The app is called ChillVerify app. The Chillverify app was developed based on follow-up feedback received from the retail butcher in case study 3 concerning the issues of accessibility of meat temperature information. A prototype of the app is shown in the Appendices (See Appendix W). It shows the key functionalities of the app, which integrates provenance and cold chain verification. The app is designed to allow the meat processor to retrieve raw temperature data from the SensorPush app in the abattoir, and to register the data to an NFC-tag linked to a cloud database using the ChillVerify app. This registered temperature information aligned with provenance can be retrieved from the NFC tag by another actor (i.e. cold chain operator or the butcher) using a portable NFC enabled mobile devices to verify the temperature history of the meat in the processing segment. The app allows for more transparency in meat temperature along the cold chain. The app also provides an alternative strategy for enhancing cold chain traceability amongst small businesses operating in fragmented red meat supply chains.

10.7 SUMMARY

This section presents a summary of the interpretation chapter of this thesis. **In the industry familiarisation phase, the research confirmed that Tasmanian small businesses are to potential traceability challenges related to** meat provenance, meat safety, meat quality, and animal welfare. In the supply chain mapping phase, the research-validated a number of these traceability challenges suggesting that small businesses. The research found that while some businesses were aware of these challenges and were open to responding to these challenges them using technologies, others lacked awareness and held a negative attitude towards implementing new mobile technologies in their firms or along the chain. **In the baseline data collection phase, the** focal firms that agreed to involved in this assessment indicated that their level of visibility to some of the critical traceability challenges faced was low. This low visibility level is linked to issues of poor information quality aligned to traceability in terms of *accessibility, accuracy and fresheners and currency*. The research also observed a critical information quality criteria “format”, to be significantly impacting visibility and capacity for traceability in the chain.

In the technology intervention phase, the research deployed some low-cost IT solutions to enhance the visibility and capacity for traceability along the supply chain. The intervention revealed the feasibility of deploying low-cost technologies amongst small businesses. It also revealed new roles in traceability including in areas of animal behaviour monitoring, temperature monitoring, and cold chain verification, marketing and branding, consumer engagement and risks management. However, the intervention also led to the identification of external factors that can inhibit the successful implementation, use and potential adoption of these low-cost mobile technologies in the chain. Amongst these factors, the key issues of internet connectivity, geographical terrain, and digital participation amongst industry partners remained the most significant problem being faced in the chain. The research also found issues of organisational attitude, end-user value proposition as critical barriers to IT utilisation for supporting traceability and responding to some of the critical challenges faced.

In the technology post-intervention evaluation phase, the research found that while some actors perceived some impact in their traceability and organisational practices, others did not perceive any impact and felt that the intervention did not fit their business focus and objective of their operations. There were other overlapping social-technical factors such as limited incentive for traceability beyond compliance, limited understanding of cost-benefit of IT traceability, and the relative power in the supply chain. Amongst these factors, the issue of supply chain power is extremely significant, and this impacts the retail butchers the most. In this study, some retail butchers found it extremely difficult to influence other actors in the chain to see the value and proactively engage in information sharing during the experiment. They could not demand more information beyond compliance because of the fear that it could impair the relationship built over time. For some butchers, asking for more information could be seen as a lack of trust. For example, in case study 2, the cold chain transport decided not to participate in the study because of the possibility of implementing sensors in the truck. The retail butcher mentioned that when the discussion was held regarding the project, it was perceived by some partners as intrusive. In another case (case study 3), the butcher felt that while the experiment was successful, it was quite overwhelming considering the amount of effort required to co-ordinate all actors to share information from farm to retail. Even in the experiment (case study 3), the farmer did not provide RFID tag numbers for the sheep after the site visit and conversations held with the processor.

Finally, based on the key findings from this study and reflections on the heuristics framework, the research has generated a new small business traceability framework. The framework enables small businesses to consider how and where low-cost IT can be most effectively deployed in their supply chain segment to enhance traceability and respond to some of the critical challenges faced. The framework also allows businesses to understand what new role and the potential impact that low-cost mobile technology intervention can have on traceability and organisational practices along the red meat supply chain.

Chapter 11

Conclusion and further work

11.1 INTRODUCTION AND MOTIVATION

This chapter provides a synthesis, summary and conclusion of this exploratory study. To re-iterate the aim of this thesis: the research explores potential traceability challenges amongst small businesses in red meat supply chains in Tasmania. The purpose of this exploratory study is to understand the role and potential impact that low-cost mobile technologies can have in traceability and for responding to some of the critical challenges faced along the red meat supply chain. The remainder of this chapter is divided into four sections. Section 11.2 presents the synthesis of the research. Section 11.3 provides conclusions and recommendations to the exploratory research. Section 11.4 describes the key limitation of this study. Section 11.5 summarises the research and provides future directions for further studies.

11.2 SYNTHESIS OF FINDINGS AND REFLECTION OF LITERATURE

The research explored traceability challenges amongst small businesses in the red meat supply chain in Tasmania. The purpose of this study is to understand the role and potential impact of implement low-cost mobile technologies in traceability along the red meat supply chain. Using a three-phased strategy (pre-intervention, intervention, and post-evaluation), the research explored four multiple case studies involving 9 small businesses operating in different parts of the Tasmanian red meat industry to explore potential traceability challenges faced, and to understand how and to what extent can low-cost mobile technologies impact traceability along the supply chains.

In reflecting on the research literature, this study has generated a number of key findings across the three phases of research investigation. Firstly, concerning potential traceability challenges, the research has confirmed that small businesses face multiple traceability challenges that relate to issues of meat provenance, meat safety, meat quality/authenticity and animal welfare. Although previous studies have also identified these challenges as impacting red meat supply chains at different points (Dabbene et al. 2014; Shackell 2008; Sofos 2008), concerning meat provenance(Monahan et al. 2018), meat safety(Aung et al. 2014; Schröder et al. 2002), meat quality/authenticity (Ballin 2010), and animal welfare(Xu et al. 2019), there have very limited insights concerning which amongst these factors relate to small businesses. For example, within the research literature, critical traceability challenges affecting red meat supply chains concerning issues of meat provenance have been linked to multiple problems such as poor meat labelling(Pointing et al. 2008; Tonsor et al. 2013); meat speciation and substitution(Walker et al. 2013); product misdescription(Woolfe et al. 2004), country-of-origin labelling(Verbeke et al. 2009), non-compliance(Charlebois et al. 2014), and disease outbreak(Scoones et al. 2010). This study found that the most critical amongst these challenges relate to compliance, identity preservation, speciation, transparency and proof of meat origin. Compliance refers to the ability to maintain animal identity, based minimum OUOD traceability requirement stipulating documentation of a product from where it is from to where the animal is going and providing a timely update to animal movement through the online database. While issues of compliance are not considered the most significant challenges within the literature, this research found that amongst small businesses, many still fail to meet minimum requirements for traceability along the red meat supply chains. Factors that contribute to issues of compliance include lack of education and poor attitude amongst small business owners. Issues of identity preservation and speciation were found to be related labelling in this study.

Secondly, in the area of meat safety, previous studies on traceability challenges affecting red meats supply chains identify several critical issues such as microbial contamination (Nychas et al. 2008; Saucier 2016) and growth of pathogens(Leger et al. 2004); poor hygiene (Ghafir et al. 2008); poor processing conditions(Sumner et al. 2011). Other studies also identify cases such meat recall(Shang et al. 2017), compliance/quality assurance/meat inspection(Butler et al. 2003) and HACCP compliance (Horchner et al. 2006), detection of chemical/antibiotics residue (Alla et al. 2013), packaging techniques (Sebranek et al. 2006), and shelf life(Emanuel et al. 2020) as being significant risk factors associated with meat safety. In this study, the research confirms that while many of these challenges could potentially affect small businesses, the most notable include possibility of chemical residue detection, risk of heavy metal contamination, and risk of microbial disease, temperature monitoring, and poor hygiene.

Thirdly, in the area of meat quality/authenticity, the literature highlights several potential traceability challenges affecting red meat supply chains and these challenges are underpinned by fraud as it pertains to meat species determination(Song et al. 2019); and verification of value-add labelling associated with lifestyle preferences (e.g. vegetarianism and organic food), religion (e.g. absence of pork from some diets), or diet and health concerns (e.g. absence of allergens) (Ballin 2010). Some recent studies even align risks of meat quality to inability to support verification of intrinsic meat quality parameters (Biswas et al. 2020), product adulteration(Mai et al. 2019), improper accreditation and certification verification in the case of Halal (Al-Teinaz et al. 2020; Zulfakar et al. 2019) and Kosher (Holloway et al. 2019). While these challenges are known to impact many red meat supply chains, in this study, the most critical amongst them include the possibility for fraudulent labelling, inability to support meat speciation/differentiation, improper description of meat products, and meat substitution. This study also confirmed that small business owners face issues related to lack of awareness and limited capacity for product differentiation and marketing. In one case study, the butcher's lack of awareness concerning opportunities on applying MSA graded information for marketing is observed, indicating the inability utilise intrinsic and extrinsic meat quality information aligned to meat products for value-adding and as a selling point in the store.

Fourthly, previous studies related to animal welfare and traceability challenges in red meat supply chains are well documented within the research literature. Some of the key issues include poor transportation and handling(Castro et al. 2019), poor lairage conditions (Rudra et al. 2019), transportation time(Mendonça et al. 2019), stress (Carrasco-García et al. 2020), inadequate training and knowledge of abattoir stakeholders(Descovich et al. 2019), and incidents of bruising of the carcase(Bethancourt-Garcia et al. 2019). In this study, the critical traceability challenges affecting animal welfare in the pre-slaughter segment include issues of poor scheduling, visibility of animal handling operations, monitoring of animal behaviour/wellbeing and oestrus detection in cows. Amongst these factors mentioned regarding animal welfare, the most significant relates to the inability to monitor animal behaviour/wellbeing, and oestrus detection in cows.

When considering these challenges in the context of seven dimensions suggested by Opara (2003) and Mirowski & Turner (2014), this study finds that the most critical traceability challenges relate to issues of product, process, input, and disease and pest, and consumption traceability. Issues of product traceability can be linked to factors of meat provenance. Issues of process traceability can be lined to factors of meat safety and animal welfare. Disease and pest traceability also relate to meat safety, while consumption traceability involves the ability to improve consumer awareness and feedback of red meat traceability through mobile devices and QR code systems.

Apart from these traceability challenges and their respective dimensions identified, there were also several external socio-technical and environmental factors impacting Tasmanian small business in their traceability efforts. Within the research literature, some of these challenges include: (a) limited technical expertise (Barry & Milner 2002); (b) inadequate capital to undertake technological enhancements (Raymond 2001); (c) insufficient organisational planning (Tetteh & Burn 2001, Miller & Besser 2000); lack of understanding of the benefits that IT can provide, and how to measure those benefits (Burgess, 2002). Other studies have mentioned factors such as the influence of ownership structure and employment status of business owners (Sharma et al. 2019), poor readiness to adopt IT (Harker and Anderson, 2002), and lack of motivation (Taylor and Murphy, 2004). In this study, the most significant factors are related to issues of limited awareness, poor organisational attitude, external poor internet connectivity, equipment malfunction and failure, low digital literacy, poor literacy skills, poor internet connectivity, and limited value proposition.

The interactions with 9 small businesses owners in supply chain mapping phase and baseline data collection phase revealed several new key insights. These include the fact the most still lack awareness of potential traceability challenges faced at different points across the chain and exhibited limited interests in the use of low-cost mobile technologies. For example, **in the farm production phase**, the research found that while the farmer faced significant traceability challenges related to animal welfare, i.e. inability to monitor animal behaviour/wellbeing in the farm, this was considered a significant problem to the businesses. Furthermore, many still prefer to use visual observation as a technique for monitoring animal welfare despite opportunities provided for more visibility using the sensor monitoring system. While some studies have shown improved traceability performance using sensors for monitoring animal welfare and behaviours(Dawkins 2004), other studies have reported negligible difference between both forms of techniques for welfare monitoring(Arcidiacono et al. 2017; Van Vliet et al. 1996). This suggests that no consensus has been reached concerning the qualitative impact of the sensor monitoring system for tracking and monitoring animal welfare on the farm. This study finds similar views with the farmer, in terms of the belief that visual inspection remains the most practical approach to responding to issues of welfare as compared to the use of low-cost mobile sensing technologies.

In the meat processing phase, the most significant traceability challenge that was found to negatively impact small business owners relate to the inability to maintain visibility of temperature and identity preservation. Key observations revealed that some of the business owners continue to utilise tattoo identification as a form of product traceability, despite the widely documented evidence of the vulnerability of this approach to risks of meat substitution and misidentification of carcases(Awad 2016; Caja et al. 2004). Other key challenges include the possibility of a loss of animal identification underpinned by lost RID tags. Within the research literature, the possibility for RFID tags attached to cattle or lamb to be exposed to risks of breakage, loss or failure of RFID have been widely reported in previous studies(Stanford et al. 2001). This research confirms this issue as remaining significantly prevalent in the meat processing phase, thus suggesting the possibility of lost traceability occurring on the abattoir. **In the cold logistics chain,** traceability challenges were found to be related to temperature monitoring, in terms of the lower levels of transparency to meat temperature and the inability ability to verify compliance to operational procedure. These challenges confirmed previously identified issues that affect most red meat supply chains, in terms of compliance/quality assurance/meat inspection (Butler et al. 2003) and HACCP compliance (Horchner et al. 2006).

In the retail butcher segment, the research found increased traceability challenges amongst small business owners in the retail butcher segments covering two main key areas, including issues of meat provenance and meat safety. In terms of meat provenance, the retail butcher faces a significant challenge in their ability to verify the origin of the meat sold to consumers, and the inability to respond to consumer inquiries on product traceability. In terms of meat safety, key issues were confirmed to be related to the low levels of visibility to risks of meat temperature abuse and refrigerating performance. Most of the butcher had difficulties in assessing the performance of the cold rooms and in ascertaining the origin of temperature abuse in the store. In some cases, the issues were traced to poor staff behaviour. In the area of meat quality, most of the butchers were unaware of how to utilise meat quality information for value-adding partly due to poor awareness and the lack of a verification system. These were the most significant traceability challenges facing the retail butchers, and are consistent with other studies that have reported similar issues concerning small business retail stores (Manning et al. 2015). However, the research also found that amongst retail butchers, the deployment of the new mobile app to support product traceability in the store revealed markedly different experiences and consumer interests. While some consumers were interested in the apps deployed and scanned the QR codes to learn more about product traceability, others did not utilise the app nor scanned the QR codes and thus suggesting lack of consumer interests.

Another key observation is that consumer acceptance of mobile phone applications for verification of meat origin in the retail butcher store varied with different geographical locations of the stores.it is possible that this variation could be due to different consumer demographic. However, it is also possible that these variations were as a result of consumer preferences for face-to-face interactions with butcher owners in the store rather than using the mobile app. Some business owners also felt that mobile devices could be harmful to consumer engagement, especially in retail butcher store where face to face interactions are considered a significant part of building trust with clients. This research finding is in contrast to other studies that have proven that consumers are interested in knowing more about their food, for example in countries such as Japan(Clemens 2003), USA and Canada(Dickinson et al. 2003) and Europe (Kehagia, Chrysochou, et al. 2007).In this study, while there was some consumer interest in some butcher stores concerning product traceability provided through QR code verification and mobile apps, the research also found that these interests were not sufficient to support the adoption of the system on a long term. On the other hand, other studies support the hypothesis that perceived information related to food traceability could influence consumer use and adoption of the mobile app (Kim & Woo 2016). In this study, the research found a lack of interests amongst some consumers visiting the butcher concerning the use of the mobile app for verifying traceability of red meat.This observation is based on the lack of app download recorded.

The technology audit conducted across the multiple case study revealed a relatively low use and adoption of IT amongst the small business for supporting traceability along the red meat supply chain. Harker and Anderson (2002) found that lack of IT adoption amongst small businesses is linked to lack of awareness and understanding of the IT, lack of confidence and trust in new technologies, the limited managerial capacity to successfully utilise new technologies in their businesses. In this study, the research confirmed that amongst small businesses, critical issues related to low IT adoption were due to poor value proposition. Most of the small business owners involved in this study did not see any benefit of utilising new technologies in their businesses due to a perceived lack of demand need and limited regulatory requirements. However, in some businesses, the factors were also underpinned by the issue of internet connectivity and low digital penetration in many rural areas of Tasmania. Both of these two factors have been previously identified in other studies (Harindranath et al. 2008) and are validated as a significant contributor to poor IT use amongst Tasmanian small businesses operating in different parts of the red meat supply chain. However, there were other issues which relate to supply chain management factors that have been found to affect small businesses in their ability to support good traceability along the supply chain. For example, key issues such as structures of the supply chain, resource limitations, lack of familiarity with the technology and its benefits amongst supply chain partners, and lack of technology prioritisation have been suggested as contributing to the limited adoption of IT in supply chains (Vaaland and Heide, 2007). In this study, the research found new supply chain factors such as the *low volume of transactions, poor attitude and behaviour, and lack of interest as being some of the most significant areas that influence limited IT use and adoption amongst small businesses in Tasmanian red meat supply chains*, and this particularly prevalent amongst business owners in the post-slaughter supply chain segment.

Baseline assessment using the heuristics framework revealed a perceived moderate to a high perceived level of visibility to traceability challenges amongst the small business owners, indicating that they were not aware of the critical problems being faced in their current traceability practices along the supply chain. A key observation was that four critical information quality challenges were affecting small business owners' visibility to traceability challenges in relation to issues of meat provenance, meat safety, meat quality, and animal welfare. These information quality challenges include issues of *accessibility, accuracy, currency and freshness and format. The heuristics framework adopted from the work of* (Caridi et al. 2010), *initially supported the use of three criteria,* namely *accessibility, accuracy, currency and* *freshness*. In Molnár et al. (2011), the authors suggested 9 information quality metrics for assessing visibility to traceability challenges and these include *accuracy, relevance, timeliness, reliability, completeness, usefulness, credibility, trustworthiness, and being up to date. In this study, only* four information quality metrics were identified as being the most significant for assessing visibility to traceability challenges amongst Tasmanian small businesses. This metrics also makes it possible to support the identification and selection of areas where IT can play a significant role in positively impacting traceability along the red meat supply chain.

In the technology intervention phase, the research discovered new roles that low-cost mobile technologies can play for supporting traceability and for responding to challenges faced at different points of the red meat supply chain in Tasmania. For example, in the farm production phase, the deployment of cow-activity sensors played a new role to support traceability in animal welfare in the area of *animal* behaviour monitoring. Barcode meat labels deployed in the meat processor played new roles to support traceability in the area of carcase labelling (identity preservation). The use of NFC-RFID deployed in the cold chain played new roles to support traceability of red meat in terms of enhanced visibility and verification of compliance to standard meat transport operation procedure. The use of the mobile app and QR code played a new role to support traceability in terms of enhancing verification of meat origin, marketing, branding, improving consumer awareness and engagement within the store. The use of the Bluetooth® wireless sensors deployed in the butcher store played new roles to support traceability in the area of meat safety by enhancing visibility and monitoring of meat temperature, support remote monitoring, and enhance notification and alerts to temperature abuse in the retail butcher store. However, the technology intervention also revealed a new approach for understanding how low-cost mobile technologies can be deployed to support traceability amongst small businesses. Within the research literature, numerous frameworks have been suggested for understanding how new IT can be implemented to support traceability, such as the use of key data elements (KDE) and critical tracking events (CTE) proposed by Zhang et al. (2014); TraceFood framework (Eskil Foras 2007); FoodPrint framework (Smith et al. 2006), and the generic framework suggested by Regattieri et al. (2007) and (Bechini et al. 2005). These studies proposed different frameworks for implementing traceability. However, these frameworks, while helpful, have provided limited understanding for small businesses operating in fragmented chains. In this study, the research has generated a new small business IT traceability framework that provides an alternative approach for understanding how low-cost IT can be deployed most effectively and timely in fragmented red meat supply chains. The framework uses four information quality metrics that include *accessibility, accuracy, freshness and currency, and format* based on the heuristics framework adapted from Caridi et al. (2010). In Golan et al., (2004), assessing traceability have been limited 'breadth', 'depth', 'precision', and 'access', but limited in assessment criteria for both internal and external traceability. However, no single metrics for evaluating these criteria have been provided. In this study, the new framework provides five metrics and assessment criteria that can be used to support assessment of traceability and visibility in red meat supply chains. Furthermore, this framework differs from previous studies in that, rather than focus on an integrated approach, it leverages on existing OUOD traceability already utilised amongst small businesses by identifying critical areas where technology is able to make the most along the red meat supply chain.

The post-intervention evaluation phase revealed that low-cost mobile technologies could have positive, negative, and no impact of traceability, and for responding to some of the critical challenges faced in the chain. Positively, the research found that low-cost mobile technologies impacted traceability in areas of information quality, organisational awareness, changes on organisational behaviour, consumer interests, product marketing and branding capabilities, and transparency in the cold chain. A similar positive impact of IT in traceability has been reported in the food retail business, in areas of enhanced customer service, and improve management and control of organisational operations (Jones et al. 2005). Negatively, the research found that deploying mobile technologies would provide unnecessary information overload and consequently lead to an additional burden on some small businesses, particularly in the farm production stage of the chain. It is also possible that technologies could also negatively impact business value proposition in terms of perceived lack of organisational fit and value of the technology. In terms of none impact, the research also found that there were some case studies where deploying low-cost technology did not reveal any significant impact both in traceability, organisational operations, and information quality. However, despite the deployment of the low-cost mobile technologies and their availability for use in traceability, some participants continued to not see any value in the technologies and were not interested in pursuing further opportunities for their businesses. However, there were some who were interested in purchasing the equipment and are looking at customising the app for their business. Based on these findings the research concludes that barriers to enhanced traceability amongst small businesses can no longer be viewed from the perspective of cost, lack of technical knowledge, and limited awareness and limited availability of low-cost technology options. Rather, the key barriers to enhanced traceability in small businesses are linked to behavioural factors including poor attitude, lack of trust, fear of opportunistic behaviours, limited value proposition and perception of limited commercial value in the system. Aligned with these findings is the observation that the main barriers to mobile technology utilisation for traceability remains socio-organisational perceptions amongst Tasmanian small businesses rather than technical or cost-based factors. Furthermore, the research found that assessing the role and impact of implementing some low-cost mobile systems in farm settings proved to be particularly challenging. This challenge was because the experiment faced several barriers including difficult topological terrain, poor internet connectivity, abrupt changes in grazing location, the spatial distribution of livestock's, antennae sensitivity to sensor tags due to physical barriers in the farm. The studies of Handcock et al. (2009) and Turner et al. (2000) have also reported similar challenges facing the effective implementation of the sensing technologies on cattle on the farm. Kamminga et al. (2018) also reported a similar problem with implementing wireless sensor technologies in networks in farms located in remote regions. This study confirms those challenges of terrain and has suggested that a proper reconnaissance of internet connectivity strength should be conducted in certain areas of Tasmania prior to full implementation of cow activity sensors because of the negative impact that connectivity fluctuation could have on overall system performance and overall information quality. Based on these findings, the research concluded that critical factors pertinent to the successful deployment and utilisation of low-cost mobile technologies include internet connectivity, issues of digital participation, portability of technologies, and geographical location of the intervention.

11.3 CONCLUSION AND RECOMMENDATIONS

This exploratory research confirms across the cases that Tasmanian small businesses operating in the red meat industry are exposed to multiple traceability challenges that impact their ability to respond to new regulatory requirements and changing consumer desire to learn more about the origins of their meat. These challenges relate to issues of meat provenance, meat safety, meat quality/authenticity, and animal welfare. The research also confirms that the level of traceability and the use of IT remains relatively low amongst small businesses, and this may be contributing to their inability to respond to the traceability challenges in their supply chains.

Amongst the businesses involved in this study, there have been some who have enthusiastically adopted and use the trial systems and who are now seeking to invest and implement them into the future. Other businesses, however, have struggled and continue not to see value in improving their supply chain visibility and capacity for traceability. Based on these findings, it can be concluded that cost, limited awareness, training, technical know-how, and complexity of technologies can no longer be considered barriers to the successful use and potential adoption of traceability technologies amongst small businesses. Instead, the barriers that persist amongst small businesses in enhancing their traceability are linked to organisational and environmental factors including negative organisational attitude and behaviour, poor internet connectivity, poor digital participation amongst supply chain partners, issues of trust and privacy concerns, change management concerning new IT utilisation, and poor value propositions. In reflecting on the heuristic framework, early indications are that it is helpful for obtaining quantitative judgement on visibility from a focal company's point of view, however, to eliminate bias in judgement, multiple sources of data must be utilised. This is because key observations from the field show that contextual factors such as trust and relationship quality could potentially lead to judgement bias. Thus, a mixed-methods approach that involves triangulating interview responses with quantitative judgement from questionnaires and field observations can be utilised to address this shortcoming. This study has contributed to the development of a small business traceability framework. This framework provides an alternative approach for small businesses to understand where and how low-cost IT can be most effectively deployed to enhance traceability and mitigate some of the critical traceability challenges in their supply chains.

11.4 LIMITATIONS

This exploratory research acknowledges some limitations that affected the findings of this study. Firstly, this exploratory study has limited traceability to four key areas, namely meat provenance, meat safety, meat quality/authenticity, and animal welfare. These four areas of traceability (i.e. meat provenance, meat safety, meat quality/authenticity, and animal welfare) were selected based on a review of literature which showed these areas as being the most significant traceability potentially affecting conventional red meat supply chains, particularly amongst small businesses. However, during this study, the research was able to further validate the findings from the literature regarding this traceability and confirmed that issues of meat provenance, meat safety, meat quality, and animal welfare pose the most significant challenges amongst Tasmanian small businesses in their supply chains. However, given that there could be other traceability challenges facing small businesses, the research would like to acknowledge this as a limitation of this study.

Secondly, the information quality criteria used to assess visibility within the framework is limited to three main criteria, and these are accessibility, accuracy and currency and freshness. These were the most significant information quality criteria where low-cost IT can play a positive new role in impacting traceability and for responding to some of the most critical challenges faced by small businesses at different points along the red meat supply chain. Thirdly, the research utilised a multiple case study methodology to guide the conduct of this study. A significant limitation of a case study methodology is the lack of generalisability of the findings. This means that the key findings the emerged from this study can only be viewed as a snap-shot of a broader phenomenon concerning traceability challenges amongst small businesses, and the role and impact of low-cost mobile technologies.

11.5 FUTURE RESEARCH

There are a number of new findings that emerged from this study that fell beyond the scope and objectives of this exploratory research. For example, this study finds that trust and communication could be two key dimensions of supply chain relationships that negatively influenced the capability for the wholesaler to ascertain traceability in the chain Previous studies have also mentioned that dimensions of supply chain relationships such as trust, commitment, adaptation, communication and collaboration could influence IT use and adoption amongst small business along the red meat supply chain (Fynes et al. 2005) . This study could not validate if a correlation exists between these dimensions of supply chain relationships and small business ability to utilise and adopt new low-cost IT in their supply chains for supporting traceability and responding to challenges faced. However, the research did find that certain beliefs and supply chain relationships held by stakeholders posed significant obstacles to IT Traceability along the red meat supply chain, thus suggesting potential relationships Further work could also look at how significant are these different dimensions of supply chain relationships and to what extent do they affect or influences small business perception of the role and potential impact of IT on traceability both within individual businesses and along the supply chains. While this area of traceability challenges i.e. supply chain relationships, falls beyond the scope of this study, it shed new areas where further work could concentrate, particularly amongst Tasmanian small businesses and in the contexts of red meat traceability.

Another key area that warrants further study is the limited awareness and negative perception held by some local beef seller concerning the value and importance of MSA based traceability for responding to challenges of meat quality in the chain. In one case, the research found there were negative beliefs held by certain stakeholders concerning the value of MSA grading system due to the perceived lack of transparency. While this belief is in contrast to other studies that have suggested MSA as being a transparent system for the traceability of meat quality(Watson, Polkinghorne, et al. 2008), this study finds that negative perceptions held inhibited the use of IT in this area. The research finds that this traceability challenge is due to poor education and limited understanding related to MSA based traceability. Further work could examine how technology could be deployed to provide better education and sensitisation of local butchers concerning MSA based traceability, and the impact this can have on capacity for traceability and responsiveness to risks related to meat quality along the red meat chain.

There were also challenges observed in the saleyard operations in relation to traceability which could not be explored due to lack of participation. These include the impact of poor scheduling practices on traceability and meat quality and lack of transparency on transit times for livestock along the chain. In this study, key observations in the pre-slaughter segment revealed significant issues of poor transparency amongst local farmers concerning the treatment and handling of calves during transportation. This lack of transparency is perceived by industry and government stakeholders to contribute to significant financial loss due to stress and poor meat quality, particularly amongst many small hobby farmers. These findings could benefit from further research, including further testing, validation of the developed framework generated in this study. Other areas include the following:

1) More methodological work is needed to validate the proposed small businesses framework to identify new metrics which could better characterise visibility and traceability in small business supply chains. Further research could begin with the information quality and transparency metrics suggested by Molnár et al. (2010), and to ascertain which of these metrics can be used to conceptualise visibility and traceability more broadly in other agri-food supply chain
2) Further work is needed to validate the application of the Chillverify app developed from this study. The app was conceptualised and developed by the PhD candidate to improve transparency and verification of compliance along the cold logistics chain using NFC cloud-based authentication. However, the app could not be deployed, tested, and validated in the case studies due to debugging issues and the limited time allocated to complete this PhD studies. Further research could explore the validity of the app and potentially extend its applicability in other agri-food supply chains with small businesses.

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Appendices

APPENDICES
Appendix A

Description: Information sheet utilised as part of the recruitment materials approved the the University of Tasmanian Research Ethics Committee.

Participant

Information Sheet

Version 1 14th July ,

2016

Investigating the role and potential impact of information technology on traceability within small and medium sized enterprises (SMEs) beef chains in Tasmania

The following information sheet is for participants in the study named above.

1. Invitation

This research is being conducted in partial fulfilment of a Doctor of Philosophy (PhD) degree in Information Technology for Mazino Amuno under the supervision of Associate Professor Paul Turner and Dr Mohammad Sadegh Taskhiri of the University of Tasmania.

Associate Professor Paul Turner and Dr Mohammad Sadegh Taskhiri are researchers in the School of Engineering and ICT at the University of Tasmania. They will be supervising this project.

2. What is the purpose of this study?

This study aims to understand the role and impact of information technology on traceability among SMEs in the Tasmanian beef industry?

3. Why have I been invited to participate?

You have been invited to participate because you have contacted the student investigator via the telephone number provided on the advertisement sheet to indicate your interest to participate in this study. However, your involvement in this project is completely voluntary and refusal to participate will not impact your relationship with the University in any way.

4. What will I be asked to do?

You will be asked to schedule a time with the researcher to participate in a personal face – to-face interview at your office or via the telephone. This interview should take between 30- 60 minutes.

If you are an actor in the beef supply chain, you will be interviewed twice during this study. Both interviews will be conducted at your business address involves a set of questions aimed at understanding the role and impact of information technology on traceability within your enterprise. Then a mobile web tool will be proposed. You will be asked to participate in the adoption of this tool with the possibility of enhancing traceability within your enterprise. Your participation in this exercise is voluntary.

If you are involved in regulatory matters related to beef traceability, you will be interviewed only once.You will not be asked to participate in the adoption of a mobile web too.

You will be informed when the interview is over. After the interview process, you will have the opportunity to review and correct the transcript of voice recordings before data analysis is conducted.

You will **not** be identified by the original name of your organization or by your own name. Instead you will be identified with letters (e.g. Company A).

5. Are there any possible benefits from participation in this study?

The findings from this study will aim to contribute to a better understanding of the role and potential impact of implementing affordable IT applications for the purpose of enhancing traceability in SME beef chains in Tasmania..

6. Are there any possible risks from participation in this study?

There are no foreseeable risks from participation in this study.

7. What if I change my mind during or after the study?

You are free to withdraw your participation from the study at any time, without needing to provide an explanation. This can be achieved by simply e-mailing the researcher with your intent. Upon request, any data you have provided to the study, including voice recordings and documentary evidence of traceability practices will be completely erased from the UTAS system hosted at the School of Engineering and ICT and cannot be retrieved.

8. What will happen to the information when this study is over?

All data will be stored in a secured system hosted by the School of Engineering and ICT at the University of Tasmania. After the research project is complete, data will be kept in an unidentifiable format for 5 years from the date of first publication, and stored on a secure server in the school of Engineering and ICT at the University of Tasmania at which point all electronic information will be deleted.

Your data will be treated in a confidential manner and not shared with any third party.

9. How will the results of the study be published?

The results of the study will be published as part of the thesis written by Mazino Amuno. Participants will not be identifiable in the publication of the results .A summary of the results will be available on the Research webpage of the School of Engineering and ICT, University of Tasmania (http://www.utas.edu.au/engineering-ict). Results of the study can also be provided upon request via email by contacting the student investigator: Mazino Amuno (email: mazino.amuno@utas.edu.au).

10. What if I have questions about this study?

You may contact the researchers of this study using the details below.

Associate Professor Paul Turner

To contact, please email paul.turner@utas.edu.au

Dr. Mohammad Sadegh Taskhiri

To contact, please email mohammadsadegh.taskhiri@utas.edu.au

Mr. Mazino Amuno

To contact, please email mazino.amuno@utas.edu.au

This study has been approved by the Tasmanian Social Sciences Human Research Ethics Committee. If you have concerns or complaints about the conduct of this study, please contact the Executive Officer of the HREC (Tasmania) Network on +61 3 6226 6254 or email human.ethics@utas.edu.au. The Executive Officer is the person nominated to receive complaints from research participants. Please quote ethics reference number [H0016911]."

This information sheet is for you to keep for your personal records.

In order to participate in this study, you must read the consent form (which you will be required to sign on the day of the experiment), and e-mail Mazino Amuno with your name, contact details and a preferred time for your availability

Appendix A

Description: Advertisement sheet utilised as part of the recruitment materials approved the University of Tasmanian Research Ethics Committee.

UNIVERSITY *of* TASMANIA | SCHOOL OF ENGINEERING & ICT

Investigating the role and potential impact of information technology on traceability within small and medium sized enterprises (SMEs) beef chains in Tasmania

Are you involved in **CATTLE PRODUCTION, LIVE CATTLE TRANSPORT, BEEF, PROCESSING, COLD LOGISTICS, RETAIL SALES,AND REGULATORY MATTERS RELATED TO TRACEABILITY IN THE TASMANIA BEEF INDUSTRY?**

Do you document or request for more information related to the movement and history of the beef products you produce, deliver,sell, or purchase?

IF YOUR ANSWER IS **YES TO ANY OF THE ABOVE QUESTIONS**, THEN I WOULD LIKE TO HEAR FROM YOU!

This research aims to investigate the role and potential impact of information technology (IT) on traceability in small and medium scale enterprises (SMEs) beef chains in Tasmania. This research involves the following activities depending on the supply chain segment:

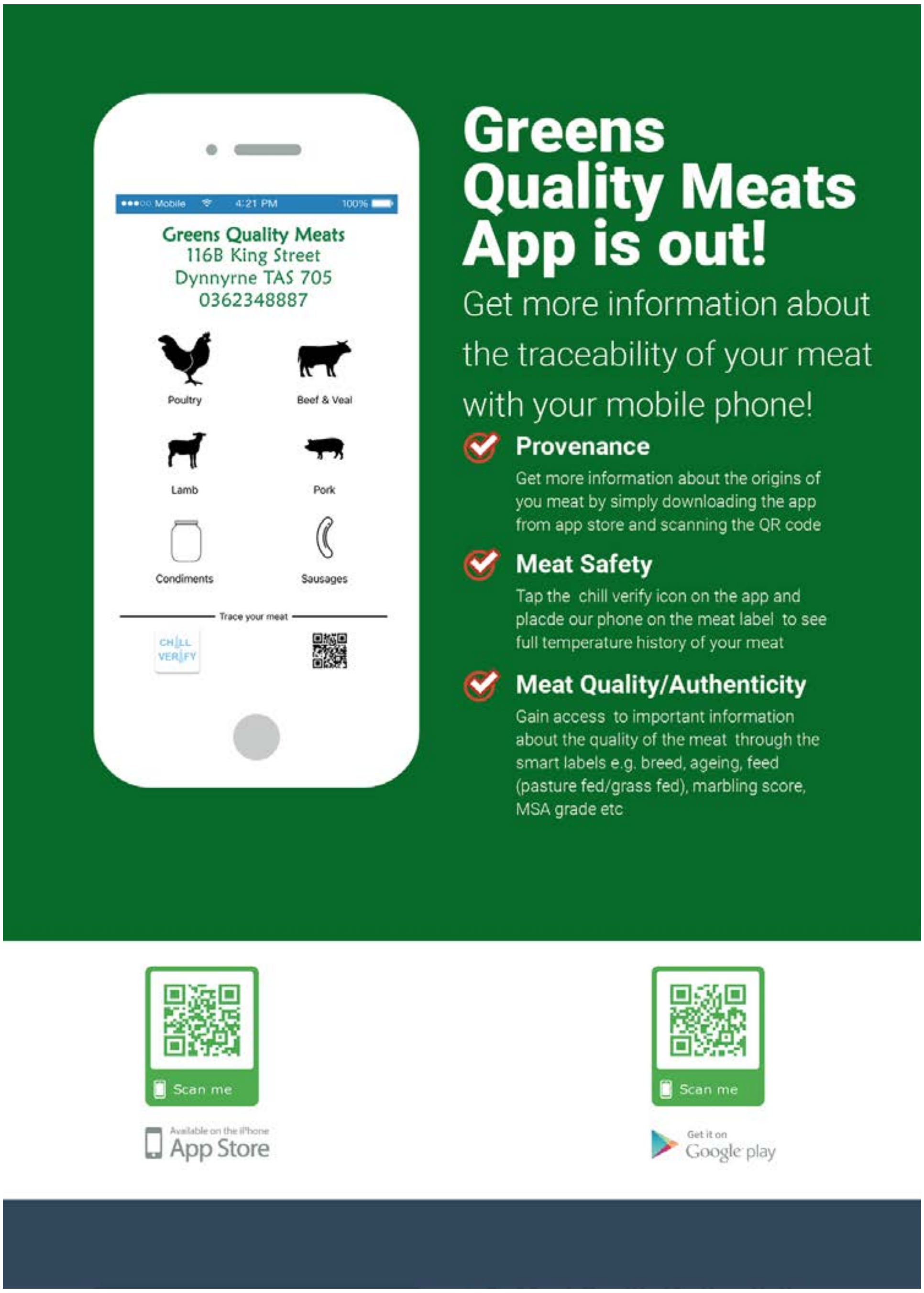
- For participants involved in regulatory matters: A short interview 30-60 mins to understand the role of IT on traceability in accreditation and monitoring of compliance in the Tasmanian beef industry;
- For actors in the beef chain, a short interview 30-60 mins to understand how you currently manage information related to Tasmanian beef in your enterprise, and what role IT may have on your current practices This will include an opportunity for your enterprise to be involved in a technology intervention experiment using a mobile web technology aimed at enhancing traceability of beef along the supply chain; and
- A follow-up 30-60mins to collect feedback on the role and potential impact of the IT intervention within your enterprise.

If interested, Please contact the student investigator on 6226 7600 to receive more information.

Your participation is much appreciated ☺ **THANK YOU**

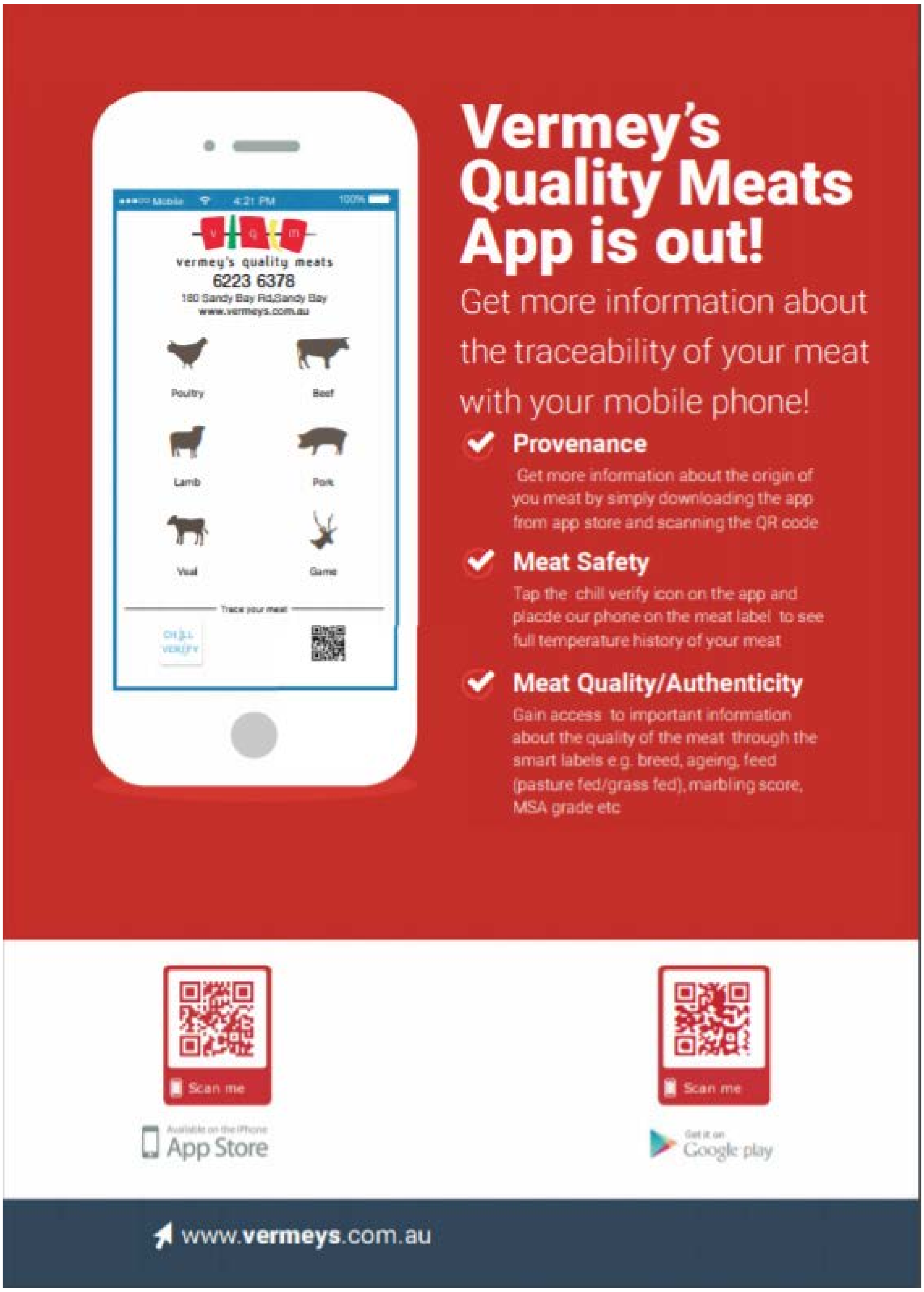
This study has been approved by the Tasmanian Social Sciences Human Research Ethics Committee. If you have concerns or complaints about the conduct of this study, please contact the Executive Officer of the HREC (Tasmania) Network on +61 3 6226 6254 or email human.ethics@utas.edu.au. The Executive Officer is the person nominated to receive complaints from research participants. Please quote ethics reference number [H0016911]."

APPENDIX B
ADVERTISEMENT POSTER FOR BUTCHER1



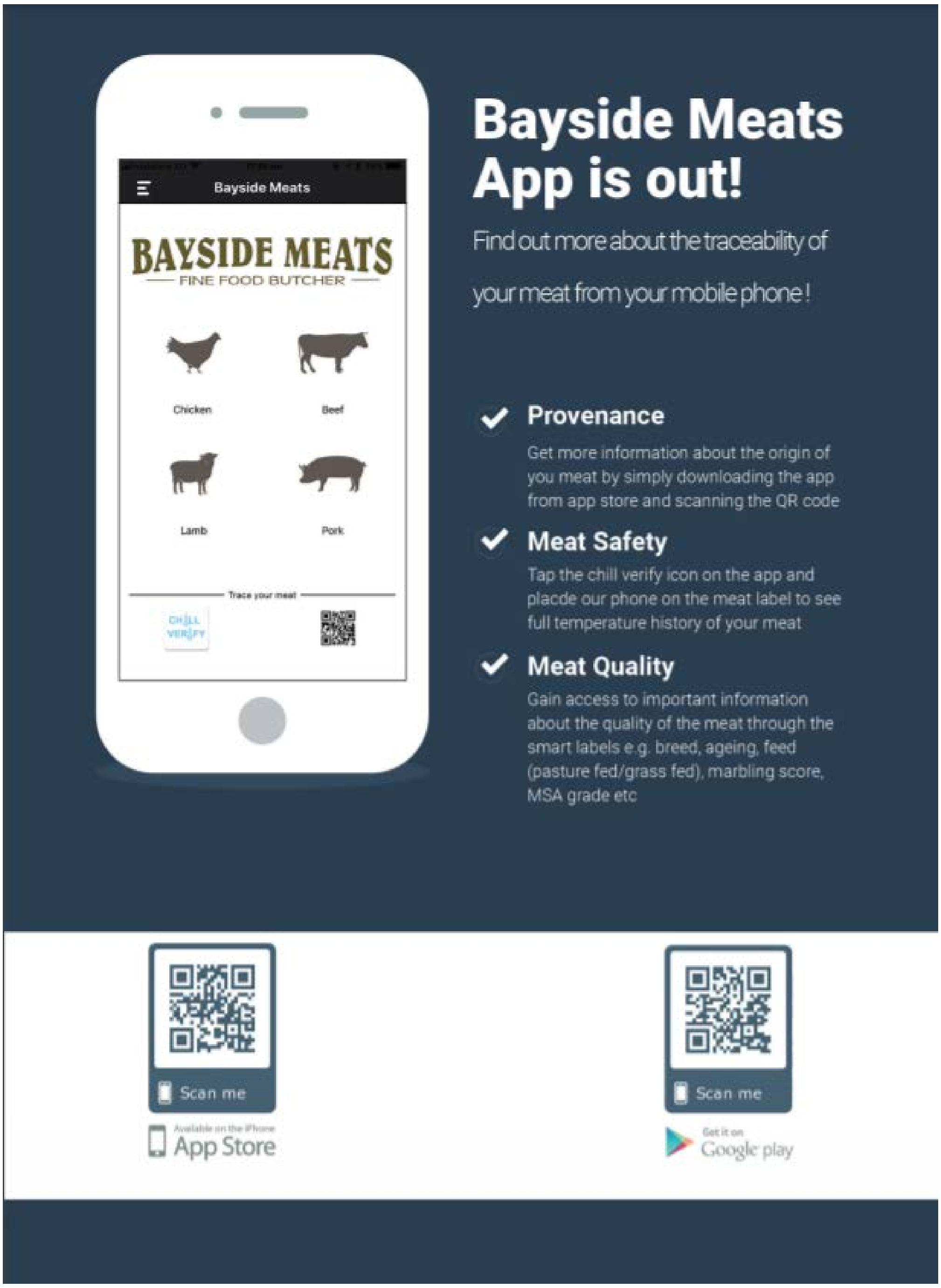
Description: Advertisement poster for technology intervention in butcher 1 involving an announcement for consumers to download a mobile app for red meat traceability and to learn more about the origins of their meat products using their mobile device.

APPENDIX B
ADVERTISEMENT POSTER FOR BUTCHER 2



Description: Advertisement poster for mobile technology intervention in butcher 2 involving an announcement for consumers to download a mobile app for red meat traceability and to learn more about the origins of their meat products using their mobile device.

APPENDIX B
ADVERTISEMENT POSTER FOR BUTCHER 3



Description: Advertisement poster for technology intervention in butcher 1. The poster shows the announcement provided to consumers during the pre-intervention phase to raise awareness of the new mobile app developed to support red meat traceability, and for consumers to learn more about the origins of their meat products using their mobile device.

APPENDIX C-

Description: Sample QR code meat verification card displayed in the butcher store to guide consumers on how to download the butcher app and to learn more about the origins of their meat products by scanning the QR code. The image on the left-hand side is the front position of the card with a QR code from mobile app scanning and interaction, while the image on the right is the back showing instructions for app download

Appendix D
Interview schedule with industry stakeholders and supply chain participants across the three-phases.

A. <u>Industry familiarisation</u>

1) Please can you describe your role in this organisation and in traceability the Tasmanian red meat industry?
2) What are your experiences dealing with small businesses in their traceability of red meat along the chain?
3) Are there any factors that can be contributing to these challenges perceived to be facing Tasmanian small businesses?

B. <u>Supply chain mapping exercise</u>

1) What is your role in this organisation?
2) Can you describe the operations involved with purchasing red meat along your supply chain?
3) Do you utilise technologies to support these operations?
4) What information du you receive, capture or share concerning the red meat product along the supply chain?

C. <u>Interview questions concerning four key themes related to traceability (i.e. meat provenance, meat safety, meat quality, and animal welfare)</u>

1) Are you able to ascertain the provenance of the red meat within your enterprise and along the supply chain?
2) Are you able to ascertain the quality/authenticity of the red meat within your enterprise and along the supply chain?
3) Are you able to ascertain compliance to animal welfare of the red meat within your enterprise and along the supply chain?
4) Are you able to ascertain the safety of the red meat within your enterprise and along the supply chain?

D. <u>Post-intervention evaluation</u>

1) What is your feedback concerning the utilisation of the mobile technology within your operations?
2) Are there any challenges with the technologies?
3) How would you evaluate the role of the technology in your enterprise and along the supply chain?

APPENDIX E-

CODING AND GENERATION OF CORE CATEGORIES FROM INTERVIEWS

Theoretical themes	Interview transcript	Sample Interview transcript with colour coding	Open codes	Axial codes	Selected codes	Core category
Potential traceability challenges	"Probably the biggest thing I think would be the time from when it's processed. I'd like to see how long it sits in the yard and sort of how to know whether they've been moved quickly , but once it goes through the system, for example the abattoirs or pig producers and to see how quickly and efficiently they move it and bring the temperature down. that will be Great. But it'd be nice to have that sort of going and follow it all the way through"	Probably the biggest thing I think would be the time from when it's processed.	Time for meat processing in the abattoir	Processing duration and condition	**Visibility of abattoir batch operations**	**Perceived traceability challenges: Meat safety and animal welfare**
		I'd like to see how long it sits in the yard and sort of how to know whether they've been moved quickly,	Accessibility and completeness of information on Animal handling, transport and lairage	Transparency of information on animal handling and care	Visibility of Animal welfare	
		but once it goes through the system, for example the abattoirs or pig producers and to see how quickly and efficiently they move it and bring the temperature down. that will be Great.	Timeliness and accessibility to information on Temperature control	Transparency of temperature monitoring and cold chain management	Visibility of the cold chain	
		But it'd be nice to have that sort of going and follow it all the way through	Accessibility to timely information on post-slaughter product traceability	Visibility of information to post-slaughter traceability	Enhanced capacity for visibility and product traceability	

Appendix E shows the method utilised for coding and thematic analysis of interview transcripts. Each participant was asked specific questions related to potential traceability challenges being faced in their supply chain segment, and the role and potential impact of IT. The first column shows the interview transcript that was obtained from one participants' perceived potential traceability challenges being faced along the Tasmanian red meat supply chain in the post-slaughter segment. The second column shows the first iteration of coding and analysis of the interview data. The third column shows the open codes that emerged from the first coding iteration. The analysis is following by the third round of coding to review the axial codes. Finally, codes are selected and organised into categories for presentation.

APPENDIX F

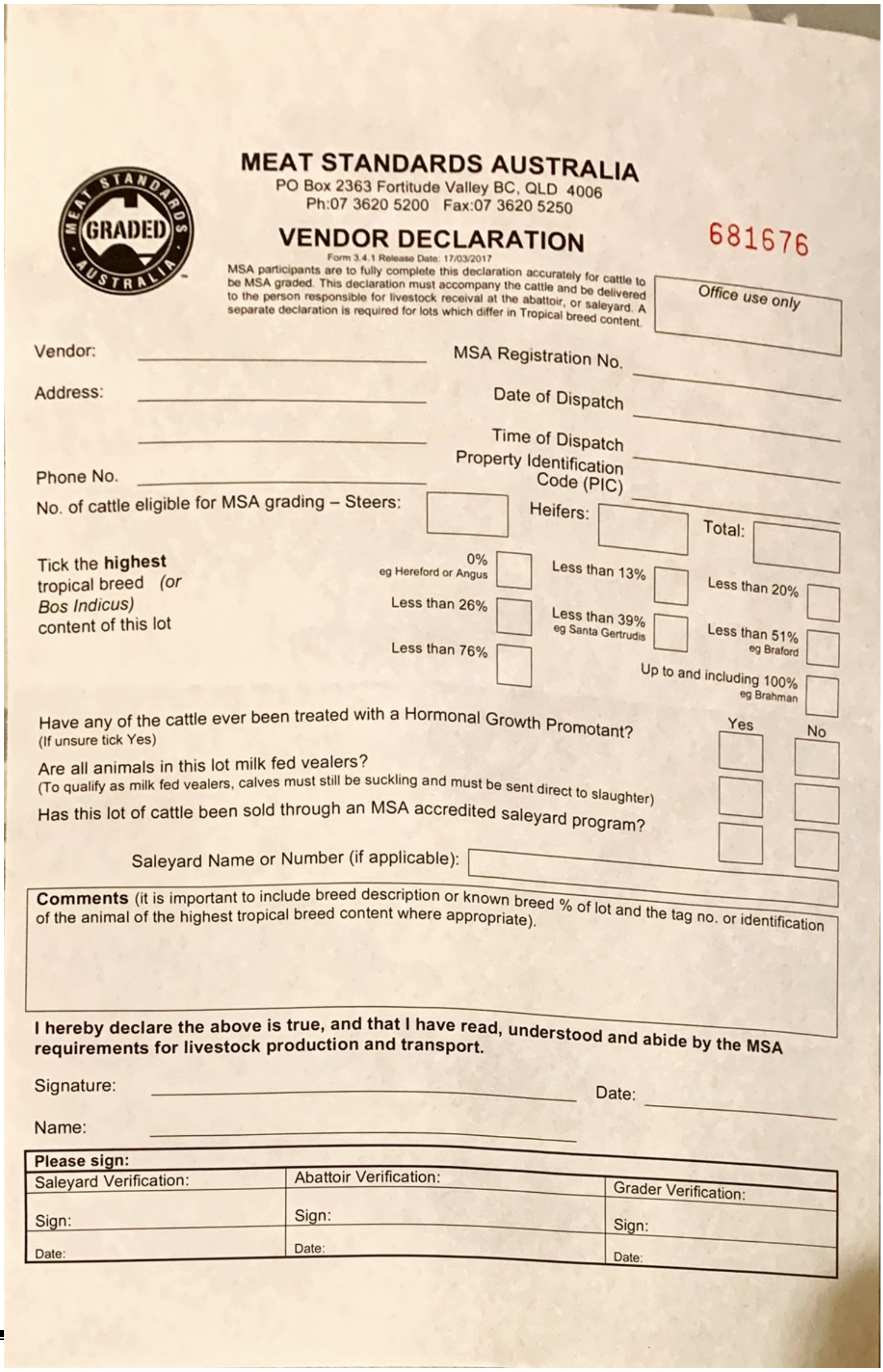
SUPPLY CHAIN MAP REFERENCE MODEL CASE STUDY 1

Information	RFID tag number ➔ PIC ➔ NVD		NVD ➔ Accreditation Certificate ➔ Feedback sheet
Technologies	Mobile phone ➔ RFID		Digital scale ➔ RFID ➔ NLIS ➔ mobile phone ➔ desktop computer ➔ wireless internet
Operations	Growing ➔ veterinary care ➔ Feeding/ Grazing ➔soil management ➔ transportation		Booking ➔ Transportation ➔ load in ➔ weighing ➔ assessment ➔ performance reporting ➔ auctioning ➔ load-out ➔ feedback
	Farmer		Saleyard

Description: Appendix F shows the application of the proposed strategy utilised to map organisational traceability practices amongst small businesses in the pre-slaughter beef chain in case study 1. The map is organised on three levels, namely operations, technologies and information. At the level of operations, the key activities of each supply chain participant are captured and mapped within individual phases in sequential order. For example, in the farm production stage, the important operation includes growing/weaning of new calves, veterinary care, feeding/grazing, soil management and transportation. In the saleyard, key operations such booking with farmers on when to pick up new stocks, transportation, load-in, and weighing of cattle, are mapped at this level. At the level of technologies, the map captures all key IT tools utilised by the business to support individual and cross-functional operations. For example, mobile phone (i..e used for communication with the saleyard) and RFID tags (i.e. used for animal identification) are the two key technologies utilised in the farm. In the saleyard, important technologies used to support the operations of the saleyard, e.g. digital scale, RFID tags/antennae, NLIS system/database, mobile phone etc., are captured to illustrate the current role of IT on traceability in this stage of the chain. At the level of information, all information generated, manipulated or shared by means of the technologies utilised are captured.

APPENDIX G

MSA NVD DOCUMENT AT THE SALEYARD



MEAT STANDARDS AUSTRALIA
PO Box 2363 Fortitude Valley BC, QLD 4006
Ph:07 3620 5200 Fax:07 3620 5250

VENDOR DECLARATION

Form 3.4.1 Release Date: 17/03/2017

681676

MSA participants are to fully complete this declaration accurately for cattle to be MSA graded. This declaration must accompany the cattle and be delivered to the person responsible for livestock receival at the abattoir, or saleyard. A separate declaration is required for lots which differ in Tropical breed content.

Office use only

Vendor: ______ MSA Registration No. ______

Address: ______ Date of Dispatch ______

______ Time of Dispatch ______

Phone No. ______ Property Identification Code (PIC) ______

No. of cattle eligible for MSA grading – Steers: ☐ Heifers: ☐ Total: ☐

Tick the **highest** tropical breed *(or Bos Indicus)* content of this lot

0% eg Hereford or Angus ☐	Less than 13% ☐	Less than 20% ☐
Less than 26% ☐	Less than 39% eg Santa Gertrudis ☐	Less than 51% eg Braford ☐
Less than 76% ☐		Up to and including 100% eg Brahman ☐

	Yes	No
Have any of the cattle ever been treated with a Hormonal Growth Promotant? (If unsure tick Yes)	☐	☐
Are all animals in this lot milk fed vealers? (To qualify as milk fed vealers, calves must still be suckling and must be sent direct to slaughter)	☐	☐
Has this lot of cattle been sold through an MSA accredited saleyard program?	☐	☐

Saleyard Name or Number (if applicable): ______

Comments (it is important to include breed description or known breed % of lot and the tag no. or identification of the animal of the highest tropical breed content where appropriate).

I hereby declare the above is true, and that I have read, understood and abide by the MSA requirements for livestock production and transport.

Signature: ______ Date: ______

Name: ______

Please sign:

Saleyard Verification:	Abattoir Verification:	Grader Verification:
Sign:	Sign:	Sign:
Date:	Date:	Date:

Description: A sample document of Meat standard Australia (MSA) National Vendor Declaration (NVD) form used by actors in the pre-slaughter segment of the beef chain registered with MSA, i.e. farmer, cattle transport, saleyard, meat processor etc., to document the movement of cattle from farm to the processor. Tin terms of product traceability, the key data elements in this document is shown, and these include the vendor (seller, e.g. farmer or saleyard), address of the vendor, MSA registration number, date of dispatch, time of dispatch and property identification code (PIC). In the area of meat quality, the NVD shows important key data elements such as breed and the presence of Hormonal Growth Promotants. At the below section, signatures from the saleyard, abattoir and Grader are used obtained to verify the authenticity of the document and veracity of details captured.

APPENDIX G

TECHNOLOGY INFRASTRUCTURE AT THE SALEYARD

Description: Image shows the technology infrastructure deployed by the saleyard to support traceability of cattle entering into the site. (a) On the top left-hand side of the picture is the internal infrastructure that includes a desktop system connected to the internet, including the NLIS database, RFID antennae, and Digital weigh scale on the ramps. (b) On the right-hand corner of the image is a photograph of the RFID antenna circuitry deployed to capture information from NLIS tag attached to each cattle entering into the premises; (c) The bottom left corner of the picture is the doorway through each cattle is loaded out and stationed for collection of weight data(d) On the bottom right corner is the photograph of the pens where the cattle are placed prior to the auction.

APPENDIX H

ACTIVATION PROCEDURE FOR THE OVI-BOVI COW ACTIVITY MONITOR

Description: Appendix H shows the instruction manual provided by the manufacturer of the cow-activity monitor Ovi-Bovi ® for operating the sensors, including the activation of tags, control of the tags through smartphone device, and NFC app/controller.

Produced by: Distributed Sensing Pty. Surganova 80-137, 220040 Minsk, Belarus www.ovi-bovi.com | info@ovi-bovi.com tel. +375 255 254 965

How to control Ovi-bovi tags via NFC on your smartphone

13 September 2018

Ovi-bovi activity detection tags have exceptionally rich and flexible functionality. They can work in basically two distinct regimes: **normal** cow activity aggregation for further detection of heat on server's level, and **datalogger** regime for raw acceleration data collection and its immediate on-air transmission for further pro- cessing and research. You can switch between normal (default) and datalogging regimes via NFC on your smartphone; and you can tweak many subtler things within each of these regimes.

Data processing algorithm on tag's level is coded in C and has a bunch of user-editable parameters:

```
uint32_t sensorId;                  // json: sid
uint32_t cyclePeriod;               // json: rate
uint32_t rumSamplesPerSquare;       // json: rsps
uint32_t rumSquaresPerMetric;       // json: rspm
uint32_t rumThreshold;              // json: rth
uint32_t rumFinalShift;             // json: rshift
uint32_t actSamplesPerMetric;       // json: aspm
uint32_t actMetricsPerGroup;        // json: ampg
```

```
uint32_t actFinalShift;          // json: ashift
uint32_t radioPLLFrac;           // json: pll
bool dataLogMode;                // json: dlog
bool ruminationMode;             // json: rumi
```

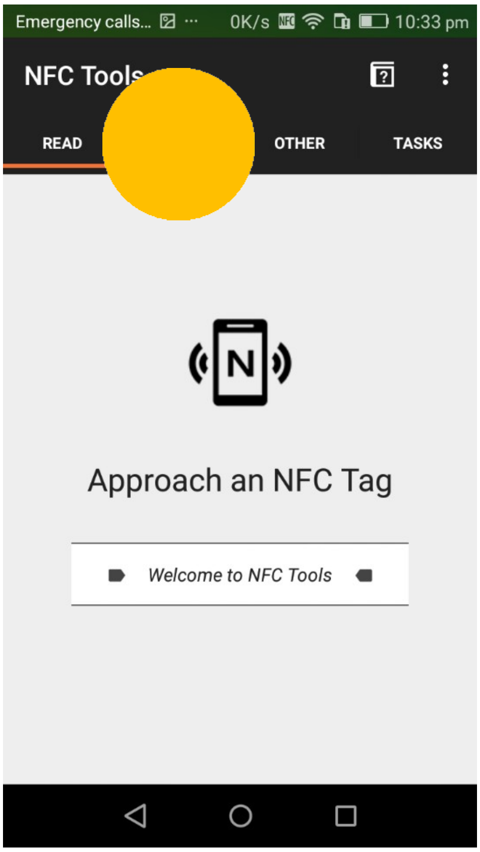
Their default settings are something like:

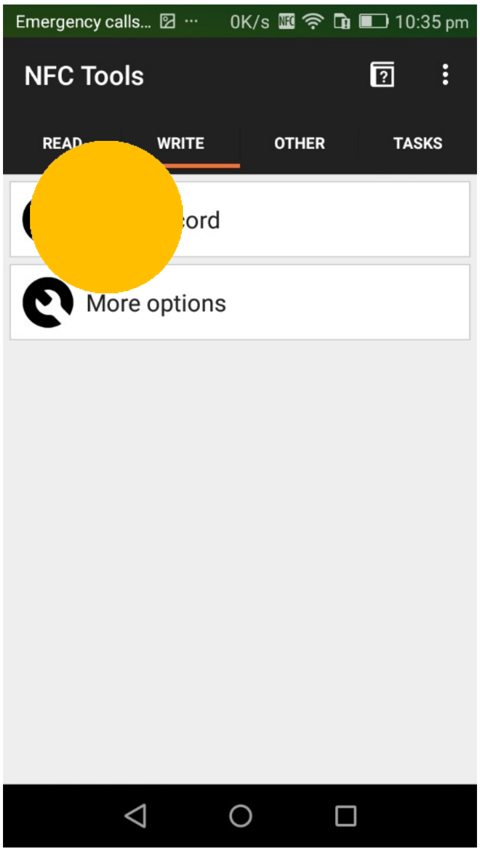
```
#define CYCLE_PERIOD_MS          500        // 500 msec between
measurements #define RUM_SAMPLES_PER_SQUARE 30      // 15 seconds
correlation length #define RUM_SQUARES_PER_METRIC 40      // 10
minutes aggregation length #define RUM_THRESHOLD 1      //
lower dX dY dZ limit
#define RUM_FINAL_SHIFT          2          // right-shift accumulated
value by #define ACT_SAMPLES_PER_METRIC   RUM_SAMPLES_PER_SQUARE *
RUM_SQUARES_PER_METRIC
#define ACT_GROUP_SIZE           2          // packet per 20 minutes
#define ACT_FINAL_SHIFT          12         // right-shift
accumulated value by #define RADIO_PLL_FRAC 0      // in pll units
#define DATALOG_MODE             false
#define RUMINATION_MODE          true
```

If we want to use tags as dataloggers, we should set `dlog` to 1 (1 means logical `true`). It is also highly rec- ommended to modify tag's number `sid` as ABC0XYZ -> ABC1XYZ (ABC stands for your client's numerical code, XYZ is your tag's number which is laser-engraved on its casing) not to mix new accelerometer data with reg- ular activity data obtained in normal regime with this same tag.

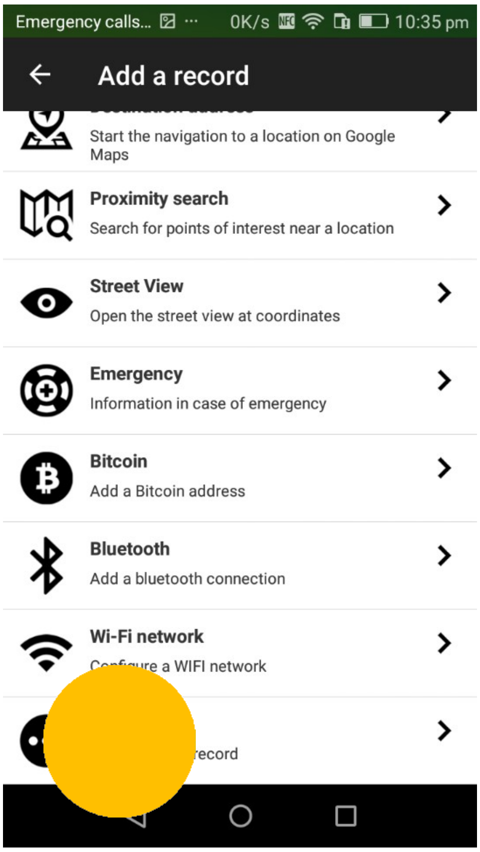
To change `sid` and `dlog`, use a mobile phone with NFC functionality. Download any free NFC editor – this can be *ST25* from *STMicroelectonics*, or *NFC Tools*, or whatever else. Assume you have *NFC Tools* installed, and your tag's full ID is 9990666 (of which you would see 666 on the casing).

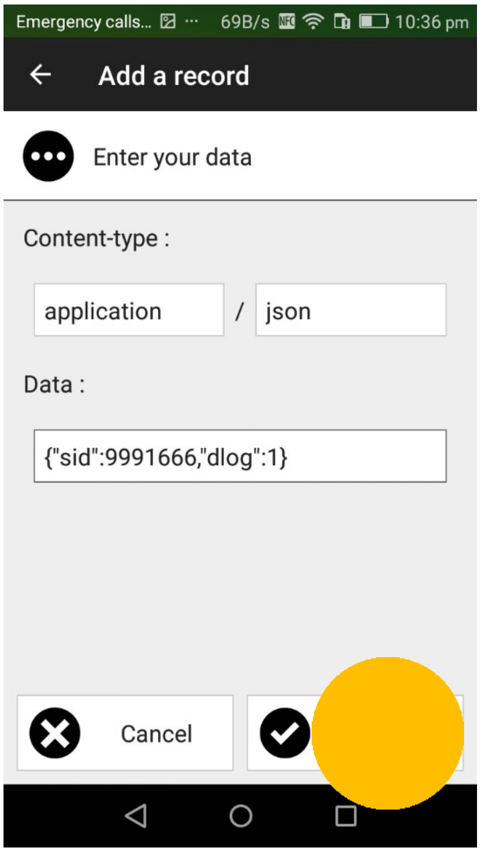
In *NFC Tools*, tap on **Write** -> **Add a record**:



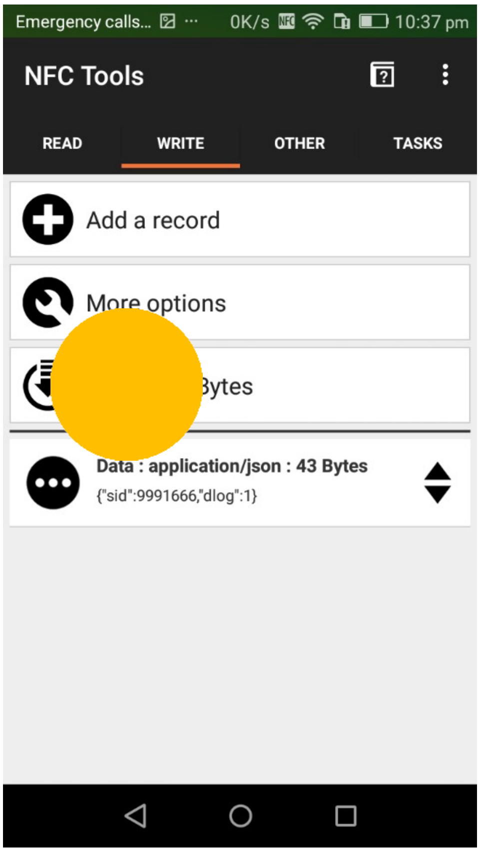


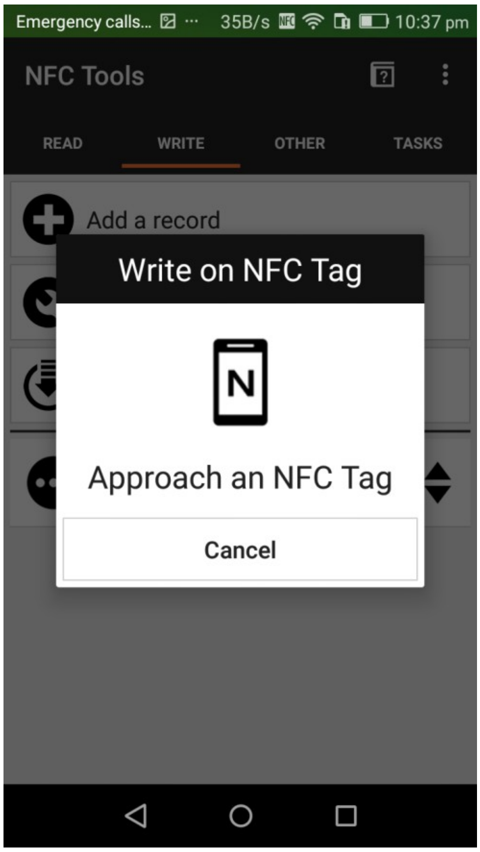
You will see a long list of options; choose **Data** at the end of. Your **Content-type** is application/json, so type this in. Then type your actual **Data** as “sid”:9991666,”dlog”:1 and confirm it by clicking **OK**:



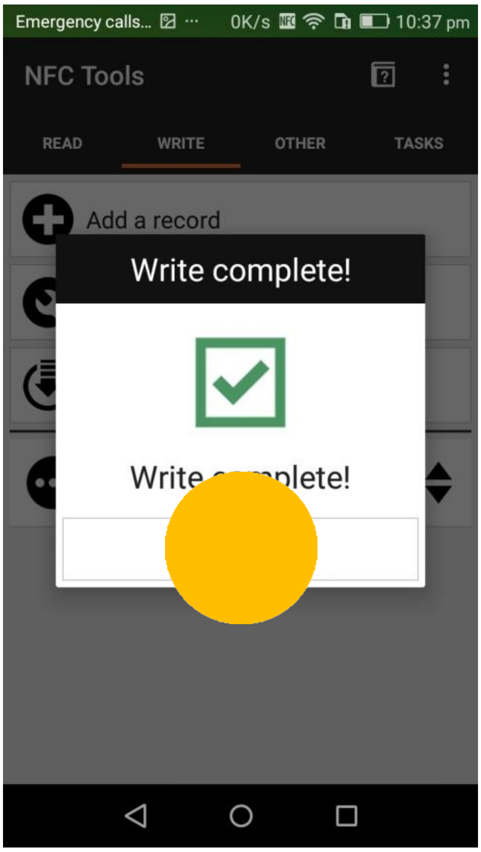


Click **Write** on the page you will see next moment, and approach your phone to the tag:

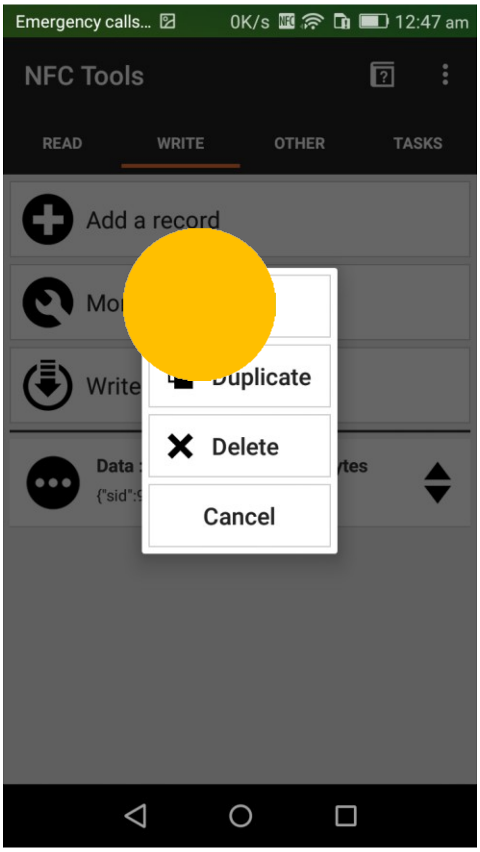


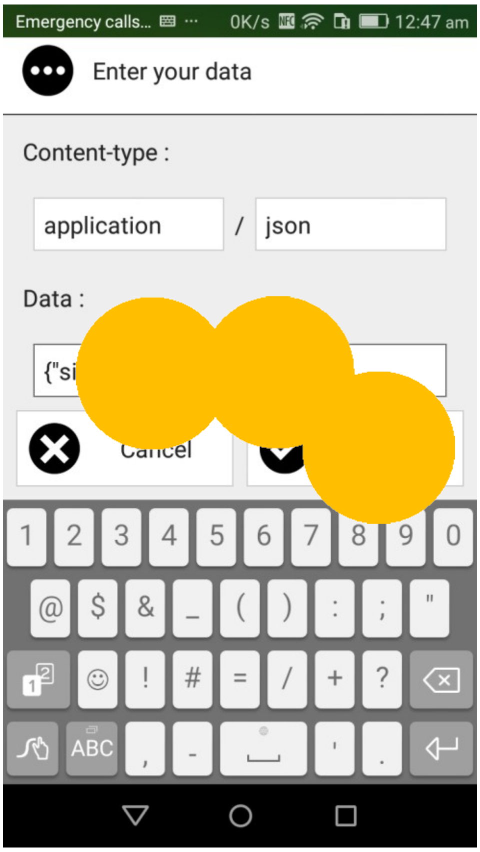


Done!

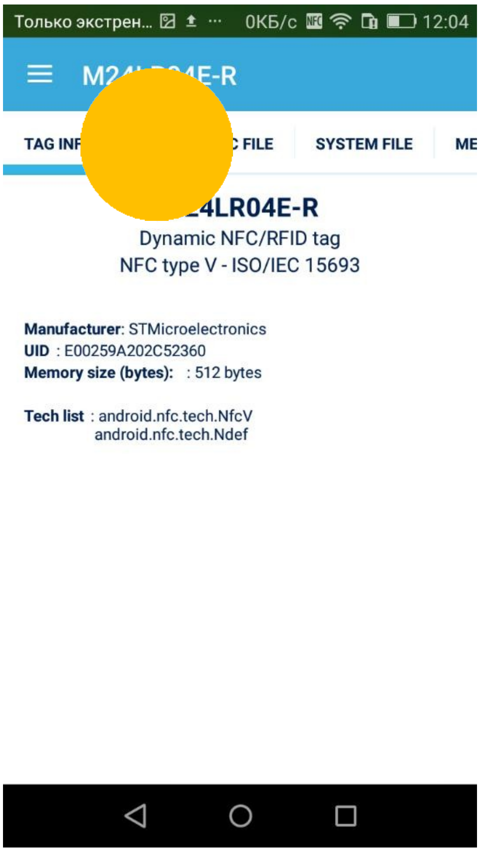


Now suppose you are to switch your tag back to normal, energy sparing regime. This is achieved by setting tag's `sid` from 9991666 to 9990666 and `dlog` from 1 to 0; in *NFC Tools* this is done through not typing the data from scratch, but editing the data still stored in app's memory:

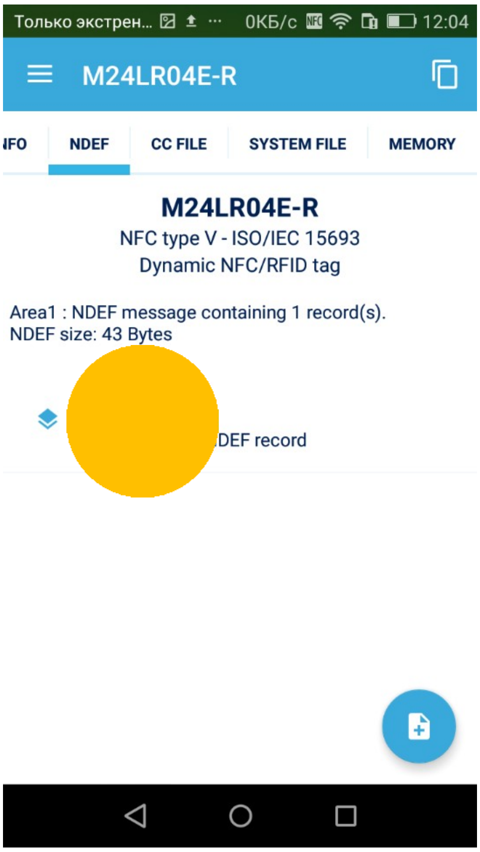




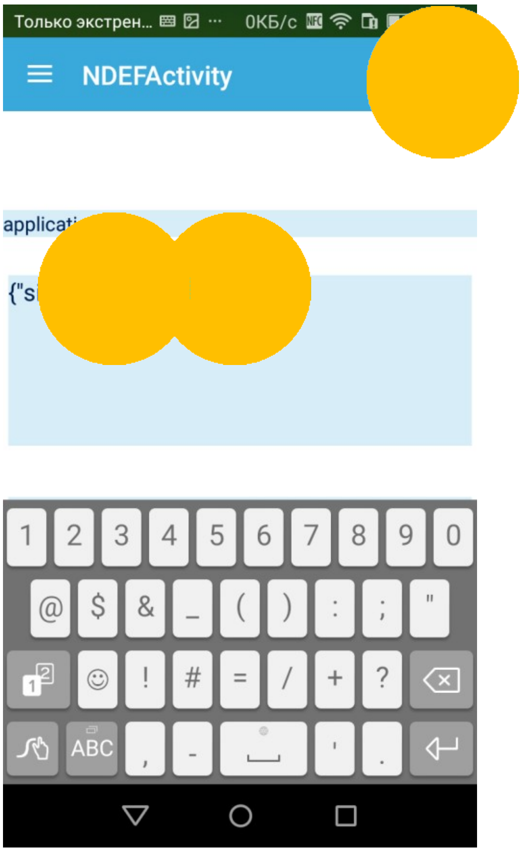
Alternatively, you may edit the data with *ST25*. First open it, read your tag, and tap **NDEF**:



Now tap **Edit this MIME NDEF record**, and then the button on the top-right to start editing:



Now you are able to change 1's to 0's in `sid` and `dlog`; after that, approach the tag with the phone until it beeps and press the button on the top-right:


Только экстрен... 0КБ/с
NDEFActivity


Только экстрен... 0КБ/с 12:22
NDEFActivity
application/json
{"sid":9990666,"dlog":0}
Writing NDEF message to Tag in progress....
Remove device from field to abort operation
Or wait until end of operation
7B22736964223A393939303636362C2264
6C6F67223A307D

Success!

Note that after writing MIME NDEF record to Ovi-bovi tag (no matter which tool on your phone you use), it takes up to **one minute** until this record is read and executed by microcontroller

APPENDIX I: MAP OF ORGANISATIONAL TRACEABILITY PRACTICES FOR CASE STUDY 2

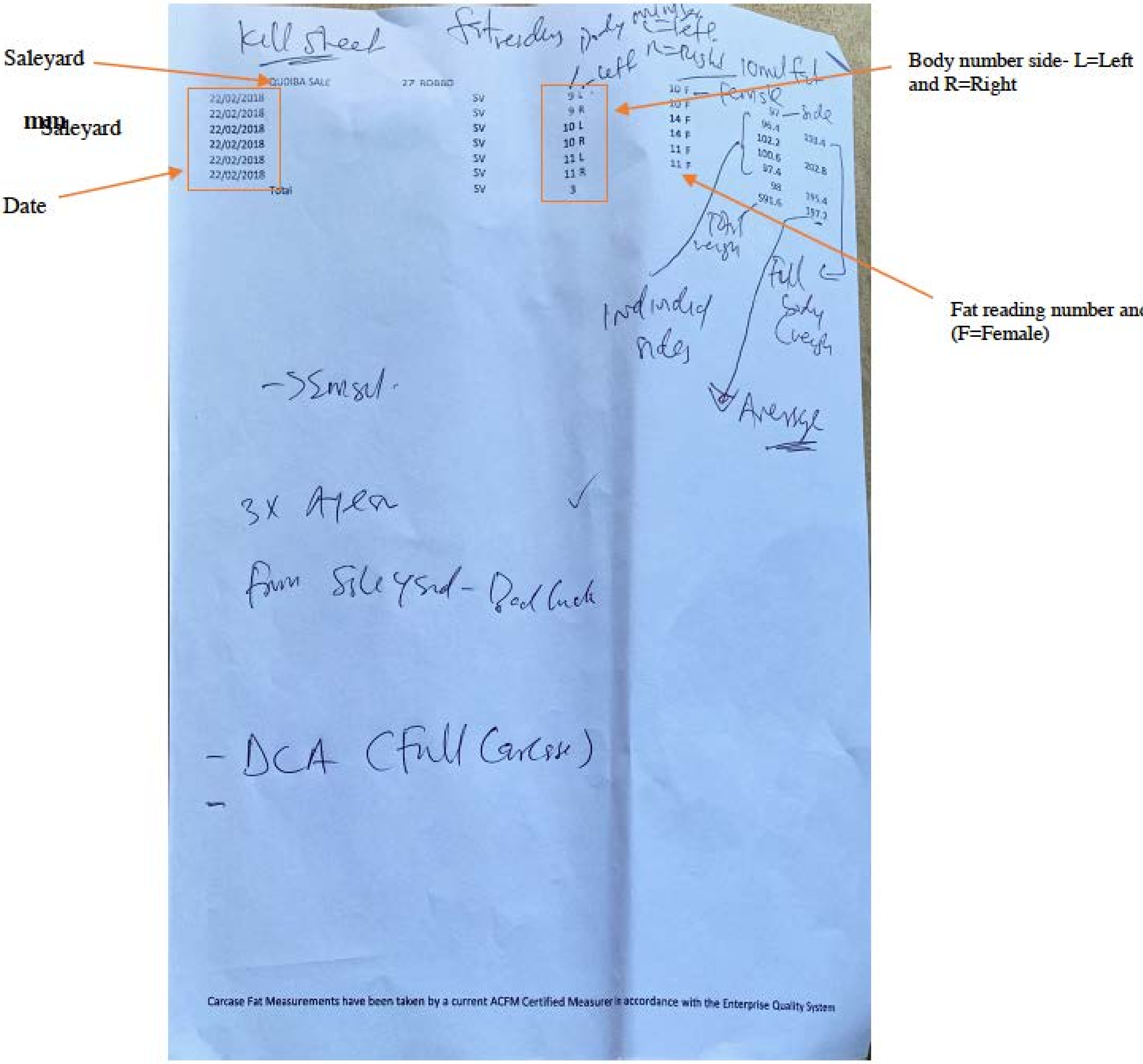
Information	NVD → kill sheet → RFID tag number		Kill sheet → carcass label		Invoice → Carcass tag → temperature
Technologies	Email → mobile phone → computer → NLIS		Mobile phone → sensor → NLIS		mobile phone → digital temperature sensor
Operations	Order receiving → Sourcing/ Purchasing → Payment → Change of ownership		Ordering processing →Purchasing → Scheduling of transportation → Receiving → Chilling		Ordering → Receiving of shipment → storage/ breakdown → display/sales
	Stock Agent		Wholesale		Butcher

Description: Map of organisational traceability practices for the post-slaughter segment of the beef chain, which is case study 2. The map shows how traceability is mapped across three layers, namely operations, technologies, and information layer. At the level of services, the key activities conducted by each participant along the supply chain segment is captured in sequential order. For example, in the stock agent state, important activities such as receiving orders from the whole or retailer, sourcing/purchasing new livestock from the farmer, payment and transfer of ownership from farm to the new buyers (i.e. wholesale or butcher) are recorded. At the level of technologies, the map shows the range of tools being used to support organisational operations. For example, in the stock agent, important techniques such as email and mobile phone are identified and captured at this level. These technologies are used to facilitate communication along the supply chain. Other technologies such as computer and NLIS databased form part of the key technologies used to support traceability of the cattle from farm to slaughter at the meat processor. At the level of information, the map captures important information that is generated, captured, shared, and/or manipulated by the technologies used in the supply chain to support organisational operations. Information such RFID tag number, farm origin, name of sender and receiver, and feed and any health challenges faced by the cattle are documents within the NVD document.

APPENDIX J:

FEEDBACK SHEET-WHOLESALER IN CASE STUDY 2

The figure below shows the sample document of a feedback sheet provided to the wholesaler by the meat processor. The feedback sheet contains essential data elements used to support traceability in the area of meat quality. These data elements are saleyard location, date of processing, Body number, and fat reading.



APPENDIX J2

CARCASS LABEL FOR wholesale

Description: The picture shown in Appendix R2 is a sample paper-based meat carcase meat label for beef that is used to maintain identity preservation within the wholesale store. The label is based on the AUS-MEAT standard that includes important key data elements such as slaughtering house name, date and time of slaughter, name of the buyer, the weight of carcase, Sex, Body number, and pen number from where the animal is sourced at the saleyard.

APPENDIX K-

SAMPLE LABEL FOR THE RETAIL BUTCHER 2-CASE STUDY 2

Description: The picture shown in this appendix is the display cabinet with an assorted range of meat products sold to consumers visiting the butcher store in Case study 2. The arrow shows the sample meat label utilised by the retail butcher to product identification and to support traceability. The data elements used in this label include the meat name, brand (optional), and price.

APPENDIX L:

SENSORPUSH TAG INSTALLED IN THE REFRIGERATING COMPARTMENT OF A RETAIL BUTCHER STORE (CASE STUDY 2)

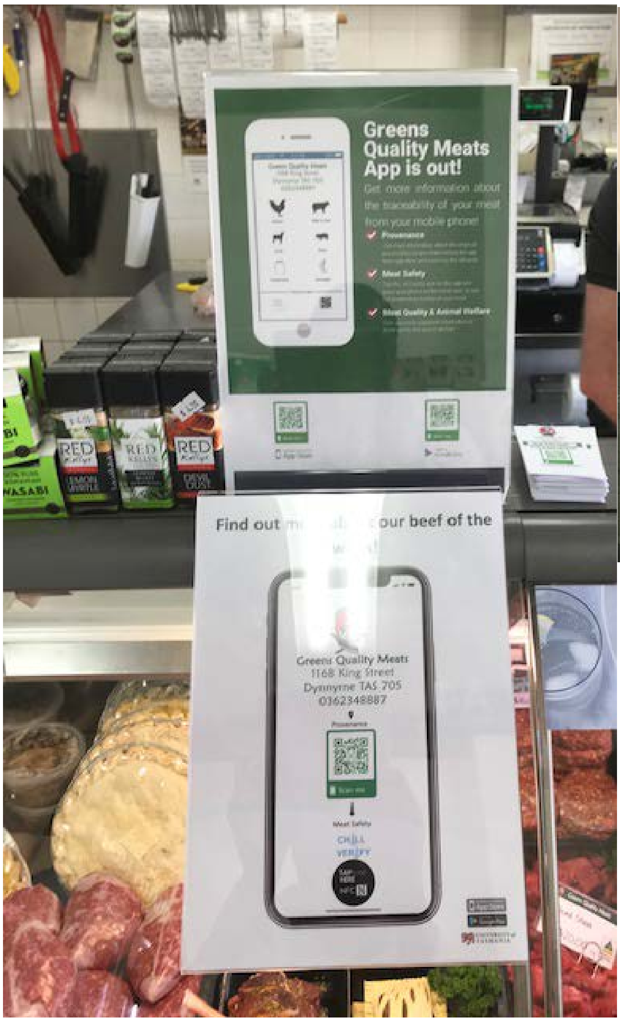
Description: Appendix L showing the installation of a SensoPush tag and an NFC temperature sensor tag deployed in the refrigerating compartment of retail butcher 1 in Case study 2. The tags are utilised to capture temperature information for fresh meat products stored in the cold room.

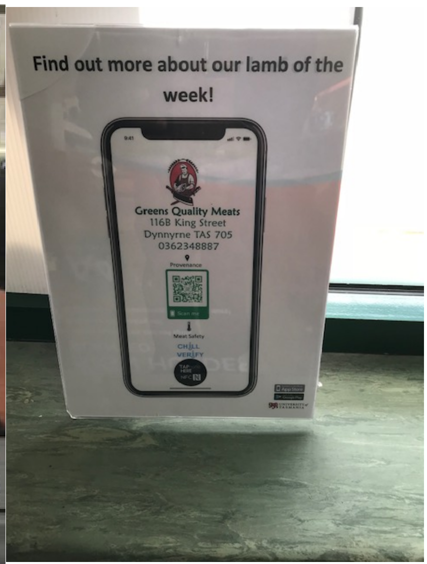
APPENDIX L2

COLD CHAIN TECHNOLOGY INFRASTRUCTURE IN THE BUTCHER STORE (CASE STUDY 2)

Description: The figure above shows the existing technology infrastructure utilised by the retail butcher (in case study 2) for monitoring the temperature condition of meat carcase in the display cabinet(left) and cold room (right) prior to technology interventions. On the left-hand corner are the digital displays of the display cabinets equipped with refrigeration sensors. On the left-hand side is the digital display for the sensors deployed in the cold room at the back of the butcher store. These photographs show the current role of IT in traceability in the area of meat safety within the butcher store and the existing amount and quality of information generated by the sensors prior to technology intervention.

APPENDIX L3
BUTCHER 1 (GREENS):
THE IMPLEMENTATION OF THE MEAT VERIFICATION APP AND MARKETING COLLATERALS.

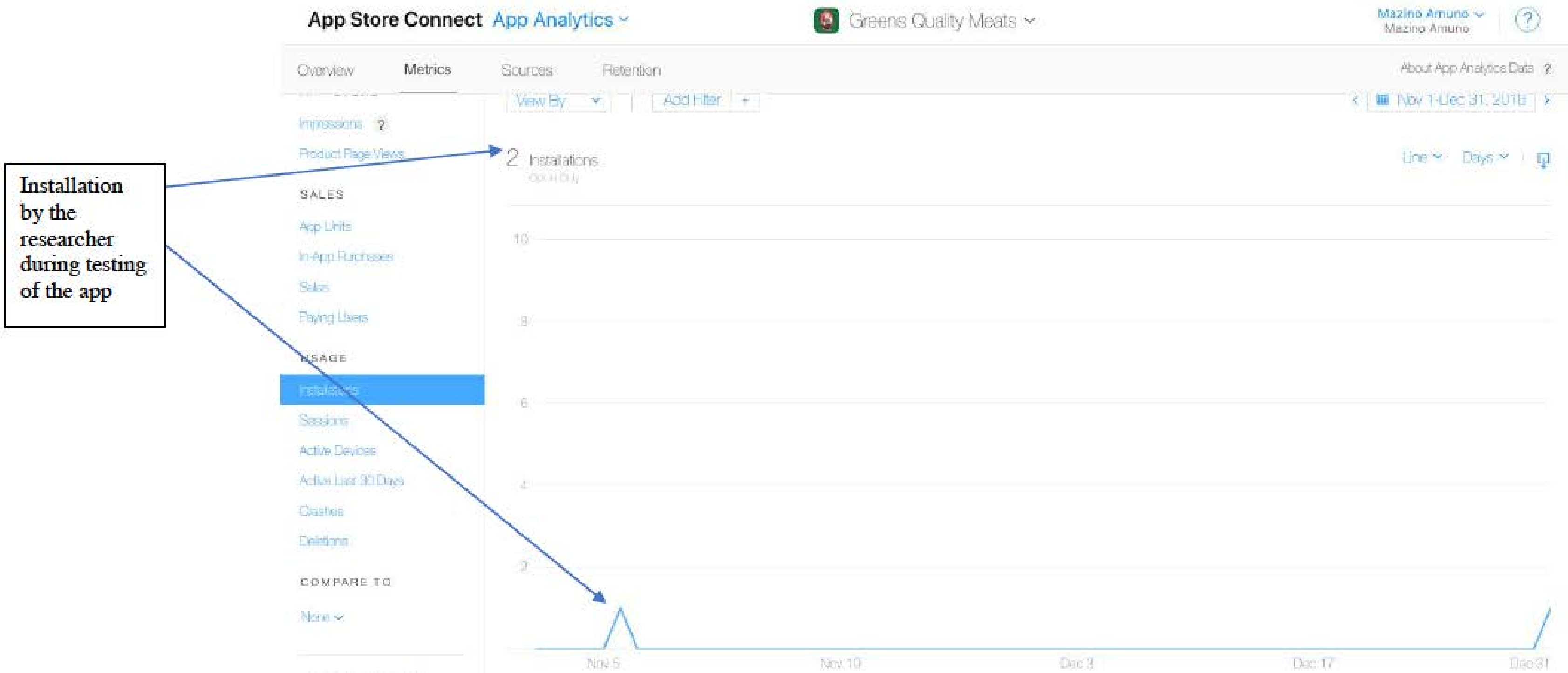




Description: The image shown in Appendix L3 is the implementation approach utilised in this butcher store to raise consumer awareness of the app and to support customer download, and also provide a method for in-store meat verification by consumers using their mobile devices. On the left-hand side is the display cabinet on which the advertisement notice is placed. Two QR code was provided to consumers to download the app for Android and iOS devices, respectively. Two QR code verifications experiment were deployed in the store to understand how and to what extent can the use of mobile verification impact meat consumers during pre- and post-purchase intervention. Both beef and lamb meats were used in this experiment.

APPENDIX M

iOS app statistics for Case study 2 retail butcher



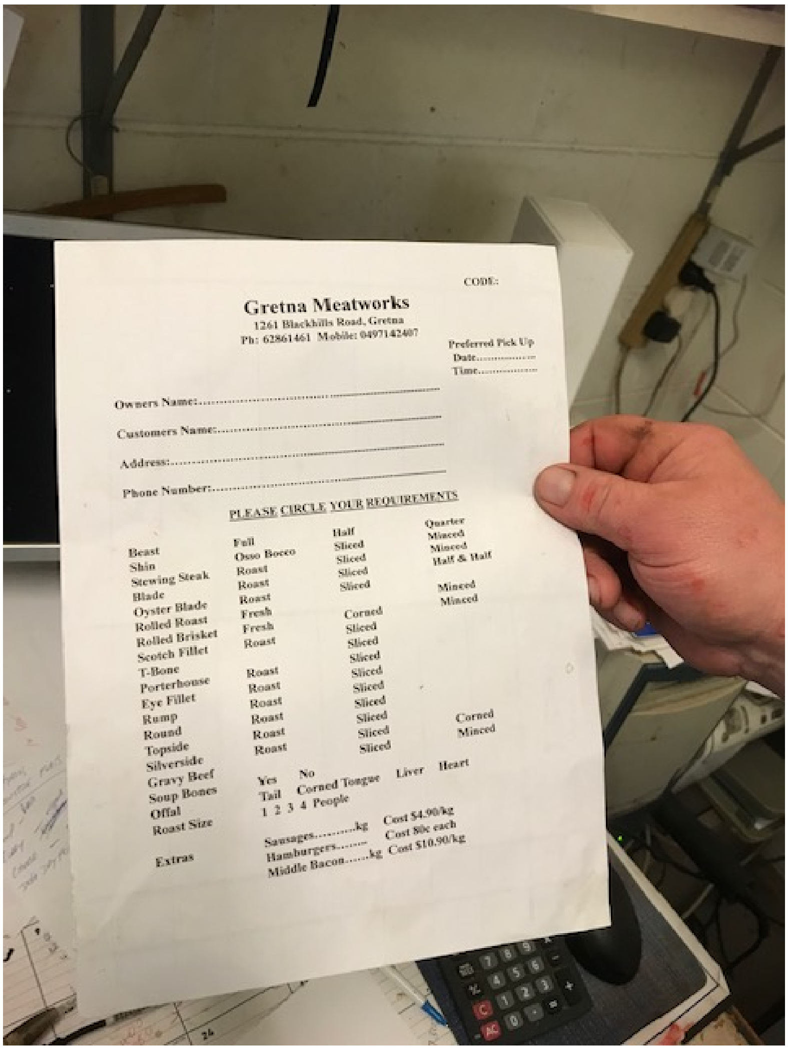
Description: The figure shown in this appendix is the Apple iOS dashboard for retail butcher 1 in case study 2. It shows the number of participants that download the butcher app from the iOS App Store. As seen in Figure above, only two installations were recorded during the period of the technology intervention in the store. Both app installs were performed by the researcher and the butcher owner during the testing phase. No customer downloaded the app during the experiment.

APPENDIX N: ORGANISATIONAL TRACEABILITY MAP OF CASE STUDY 3

Information	RFID tag number ➔ Pic number ➔NVD		NVD ➔ RFID tag number ➔ tattoo		Meat label
Technologies	RFID ➔ laptop computer ➔ digital scale ➔ mobile phone		RFID scanner ➔ desktop computer ➔ mobile phone ➔analogue sensor		Temperature sensors ➔ barcode label ➔ computer desktop ➔ mobile phone ➔ portable temperature logger
Operations	Growing➔weaning ➔ feeding ➔ vaccination ➔transportation		Booking ➔ receiving ➔ slaughter ➔ chilling ➔ load-out		Sourcing ➔ cold transport ➔ delivery ➔chilling ➔ display/ sales
	Lamb Farmer		Processor		Cold Chain/Retail butcher

Description: Map of organisational traceability practices for the lamb supply chain, which is case study 3. The map shows how traceability is mapped across layers, namely operations, technologies, and information layer. At the level of services, the key activities undertaken by each participant along the lamb supply chain segment is captured in sequential order. For example, at the level of operations, the key activities include: growing➔weaning ➔ feeding ➔ vaccination ➔transportation. These are the most significant activities routinely undertaken by the farmer. At the level of technologies, some tools identified include RFID tags, a laptop computer, a digital scale and a mobile phone. Also, the level of information, critical information generated by the technologies are captured and mapped at this layer, and these include RFID tag number, property identification code (PIC), and the NVD.

APPENDIX O
ABATTOIR MEAT PROCESSING ORDER FORM


CODE:

Gretna Meatworks
1261 Blackhills Road, Gretna
Ph: 62861461 Mobile: 0497142407

Preferred Pick Up
Date.................
Time.................

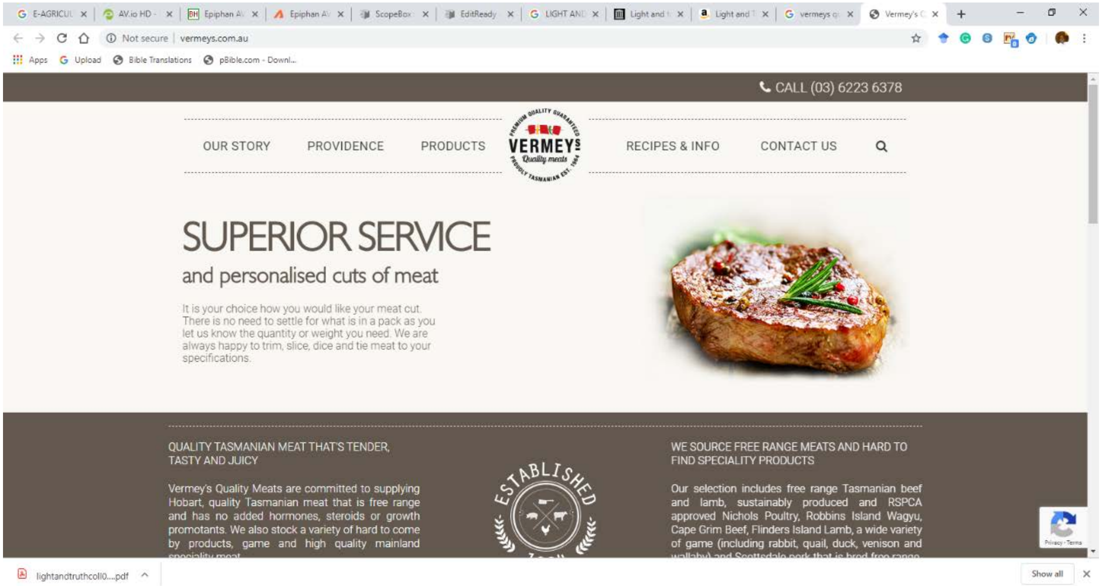
Owners Name:...
Customers Name:...
Address:...
Phone Number:...

PLEASE CIRCLE YOUR REQUIREMENTS

Beast	Full	Half	Quarter
Shin	Osso Bocco	Sliced	Minced
Stewing Steak	Roast	Sliced	Minced
Blade	Roast	Sliced	Half & Half
Oyster Blade	Roast	Sliced	Minced
Rolled Roast	Fresh	Corned	Minced
Rolled Brisket	Fresh	Sliced	
Scotch Fillet	Roast	Sliced	
T-Bone		Sliced	
Porterhouse	Roast	Sliced	
Eye Fillet	Roast	Sliced	
Rump	Roast	Sliced	
Round	Roast	Sliced	
Topside	Roast	Sliced	Corned
Silverside	Roast	Sliced	Minced
Gravy Beef			
Soup Bones	Yes No		
Offal	Tail Corned Tongue	Liver	Heart
Roast Size	1 2 3 4 People		
Extras	Sausages...........kg	Cost $4.90/kg	
	Hamburgers.........	Cost 80c each	
	Middle Bacon.......kg	Cost $10.90/kg	

Description: The picture below is a sample data sheet used by the meat processor to capture butcher slaughter preference for livestock delivered to the abattoir operations. In the datasheet, several key data elements can be identified, and these include the owner’s name (name of cattle seller), Customer’s name (buyer), address of the buyer and phone number, and meat cut preferences. The meat cut preferences is a mandatory data element which the customer must select as part of the fulfilment of orders from the abattoir. As seen in the sheet, customers also have the opportunity to choose additional value-add processing preferences such as preparation of sausages, hamburgers, and middle bacon based on extra charges.

APPENDIX Q:
WEBSITE OF BUTCHER (CASE STUDY 3)-LAMB



Description: The figure above shown in this appendix Q is the website of a retail butcher in which, information of some of the meat products sold to consumers is displayed. The website contains important information about the meat products sold by the retail butcher and these include providence (i.e. provenance) mainly for beef, list of products sold, recipes and contact address**.**

APPENDIX Q2
QR CODE VERIFICATION IN BUTCHER STORE 2

Description: The picture shown above is the implementation strategy utilised during the deployment of a mobile verification app within retail butcher 2 (case study 3).This implementation aimed to explore and understand how the use of low-cost mobile applications involving QR codes can be utilised by retail butchers to support traceability and enhance verification of meat verification along the lamb supply chain. On the left-hand side of the picture is the verification poster installed in the store to enable the consumer to scan the QR codes to learn more on the traceability of the lamb meat purchased in the store. On the right-hand side of the picture is the advertisement /poster designed in consultation with the butcher and deployed on the walls of the butcher store to raise awareness and provide direction on how to download the butcher app from Apple iOS store and Android store through using their mobile devices.

APPENDIX R

TEMPERATURE SENSOR TECHNOLOGY INTERVENTION AT THE ABATTOIR (CASE STUDY 3)

The figure displayed above in this appendix is a screenshot of the mobile phone used by the meat processor in case study 2 to monitor the temperature condition of the cold room. The mobile phone I an iPhone 5s and the app utilised is the SensorPush® app. The profile displayed in the iPhone is the temperature profile captured during the technology intervention between October -December 2019.

APPENDIX S:
BARCODE LABELLING INTERVENTION

Description: The picture in Appendix s is a photograph taken by the candidate during the meat labelling/temperature monitoring technology intervention in the meat processing plant. A total of five carcases were utilised for this experiment, in which each carcase was assigned a unique identification code, and a corresponding barcode label is generated and affixed to the carcase. The purpose of the experiment was to illustrate how the meat processor can utilise simple, low-cost meat labelling solution to enhance internal traceability of meat carcase in the abattoir and to maintain their identity till it reaches the butcher. The intervention also illustrates a method for the meat processor and retail butcher to migrate from ink-based identification methods and 2-D barcode labelling system.

APPENDIX T:

BLULOG SENSOR INSTALLED IN THE ABATTOIRS FOR TEMPERATURE TRACKING IN THE COLD CHAIN (CASE STUDY 3)

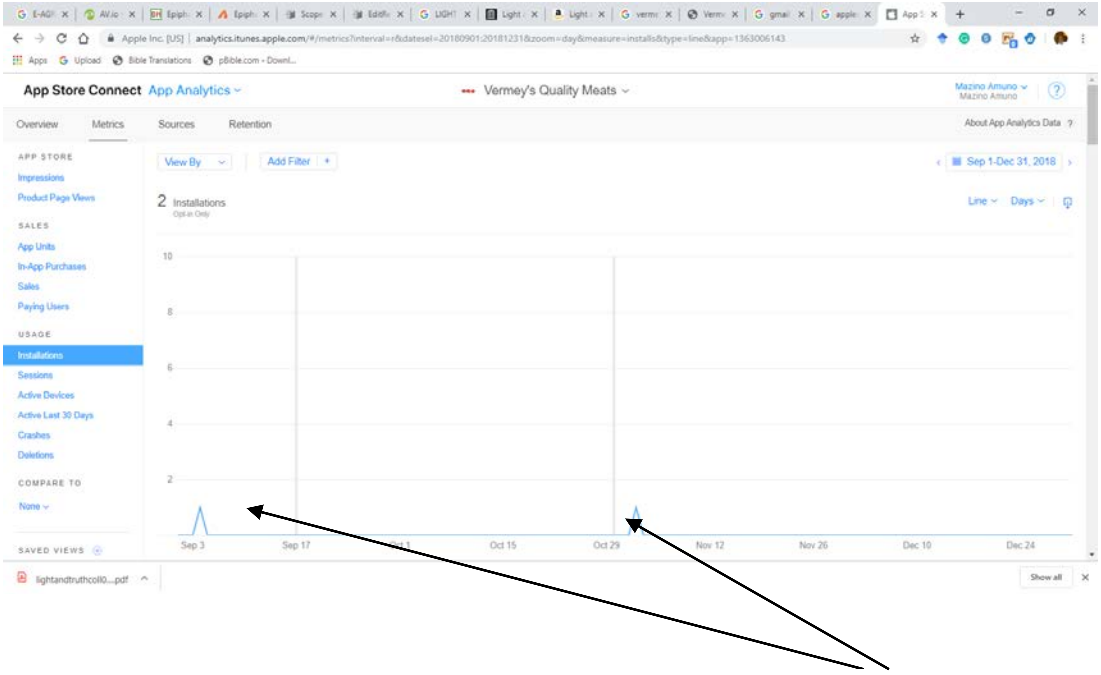
The pictures shown in Appendix T is an installation of a cold chain monitoring NFC tag being used to track temperature conditions both within the meat processor and also along the cold chain. This NFC is a low-cost portable device developed by Blulog and was deployed in Case study 3.

APPENDIX U:

USER INTERFACE OF RETAIL BUTCHER 2 (CASE STUDY 3) MOBILE APP

Description: The picture shown here in Appendix U is the user interface of a mobile meat verification app developed and implemented in case study 3. The mobile technology intervention aimed to enhance consumer ability to verify the traceability and meat in the butcher store. The mobile app consists of two main functionality, namely the ChillVerify and QR code. The ChillVerify functionality was developed to support verification of compliance in the cold chain by the consumers and to promote transparency with customers visiting the store. However, the research was unable to test the feasibility of the use of this functionality. The QR code functionality allows customers visiting the store to quickly scan a meat label or poster in the store to learn more about the traceability of the meat. Apart from the functionalities developed, the app also provides general information on the range of meat products sold in the butcher store such as poultry, pork, veal, and game. This information is accessed by the customer interested in learning more about the type of meat cuts available for each meat product and their providence.

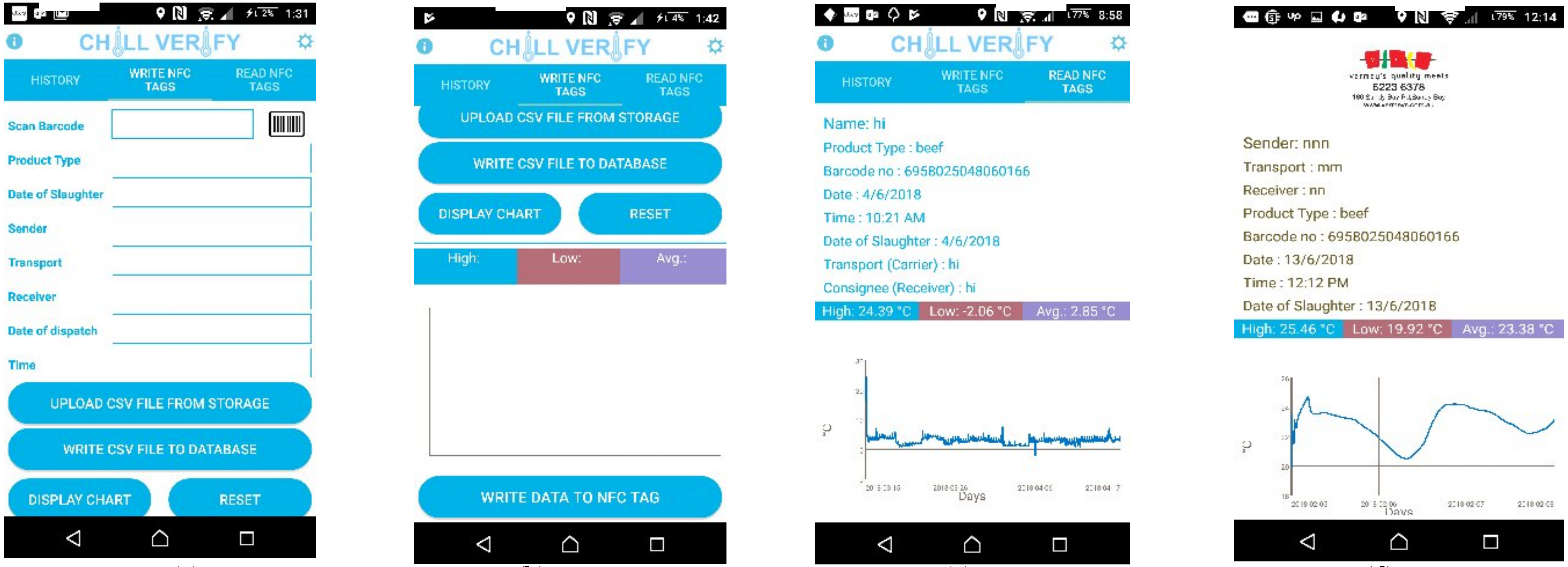
APPENDIX V:
IOS APP DOWNLOAD STATISTICS FOR RETAIL BUTCHER 2 APP



Lab testing

Description: The figure shown above in Appendix V is a dashboard of the iOS store for the mobile app developed and implemented in the butcher store (Butcher 2) in case study 3. The dashboard shows the number of customers that downloaded the app throughout the technology intervention. The 2 downloads recorded in this experiment were actual lab testing conducted by the candidate.No customer download were recorded during the technology intervention and post-intervention phase of the study suggesting a lack of consumer interest in the use of the mobile app.

Appendix W:
ChillVerify APP



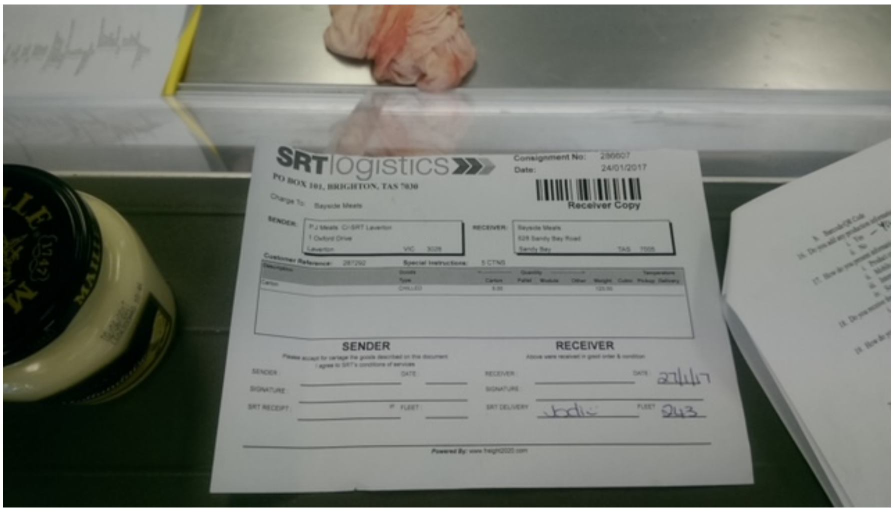
(a) (b) (c) (d)

The figure shown above in Appendix W is the ChillVerify App developed by the candidate to support transparency and traceability of meat temperature along the cold chain. However, the app could not be deployed due to time constraints. The intervention is targeted between the meat processor through the transport to the retail butcher. The app is deployed using a cloud database storage system hosted on Google. The user interface shows four main views: (a) data input view (i) history of the scanned item; (b) Write NFC tags, i.e. register a temperature profile to a meat label using an NFC tag; (c) read NFC tag, i.e. verify traceability information on the NFC card;and (d) A lab test of the application of this mobile app using sample CSV data from the SensorPush ® software.

APPENDIX Y:
MEAT LABEL in DISPLAY CABINET

Description: The picture displayed above in Appendix Y is a display cabinet in Butcher 3 store (case study 4) showing how meat products a showcased in the store and the current data elements used for identification and traceability. It shows the major key data elements utilised for product identification in the store, and these are meat type, product number and meat name.

APPENDIX Y:
WAYBILL LOWER BUTCHER 2

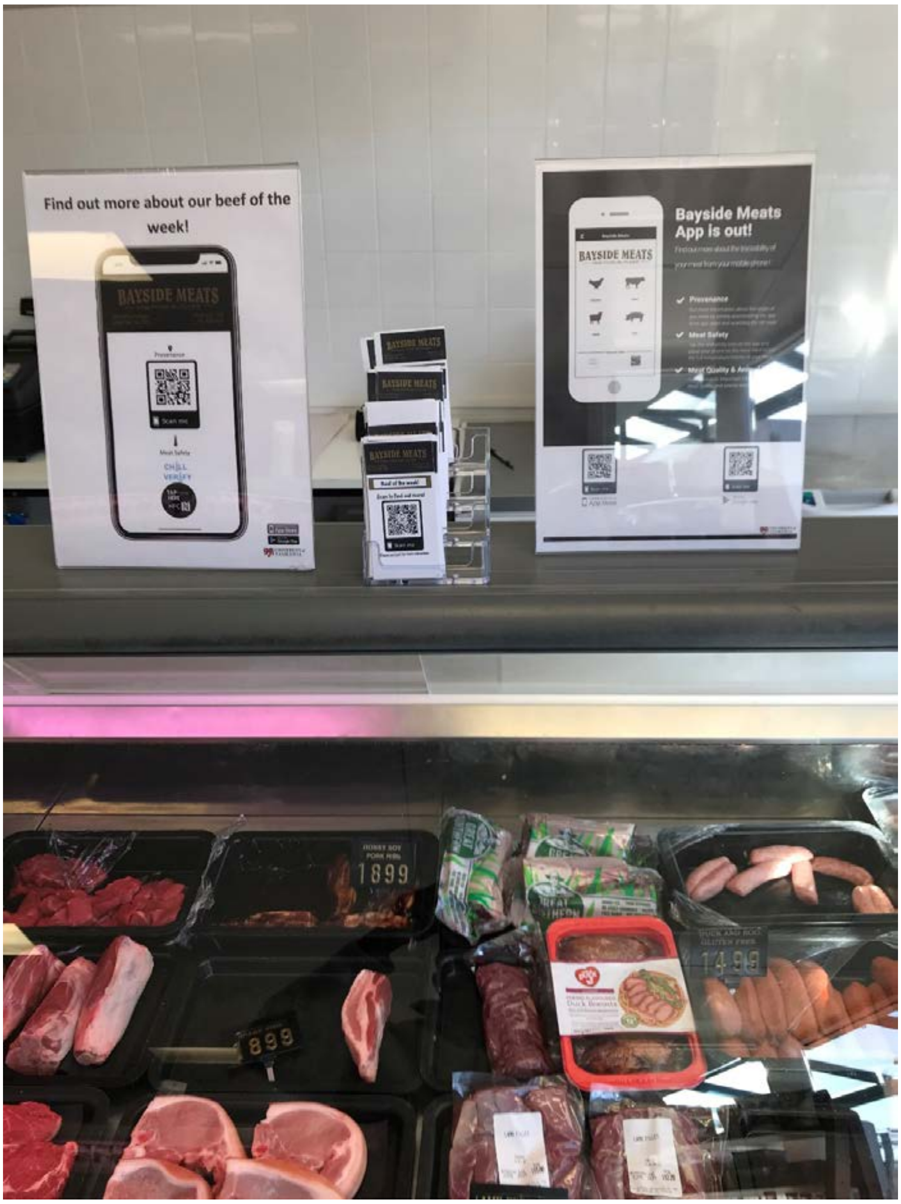


Description: The pictures shown in this appendix Y is the Waybill paper sheet that is generated by the logistics operators during the pickup and delivery of meat from the meat processor to the retail butcher. In the top picture show above, the waybill is affixed to the carton and includes several important data elements such as the name of the logistics provider, number of items in the carton, consignment number, name of receiver (buyer from the meat processor), address of the sender, and barcode number. The picture at the bottom is a sample waybill form provided to the butcher on delivery of the meat to the store. The waybill consists of similar data elements as shown on the top, and this includes data elements such as sender name, address and signature and receiver name, address and signature.

APPENDIX Z: BAYSIDE ANALOGUE SENSORS

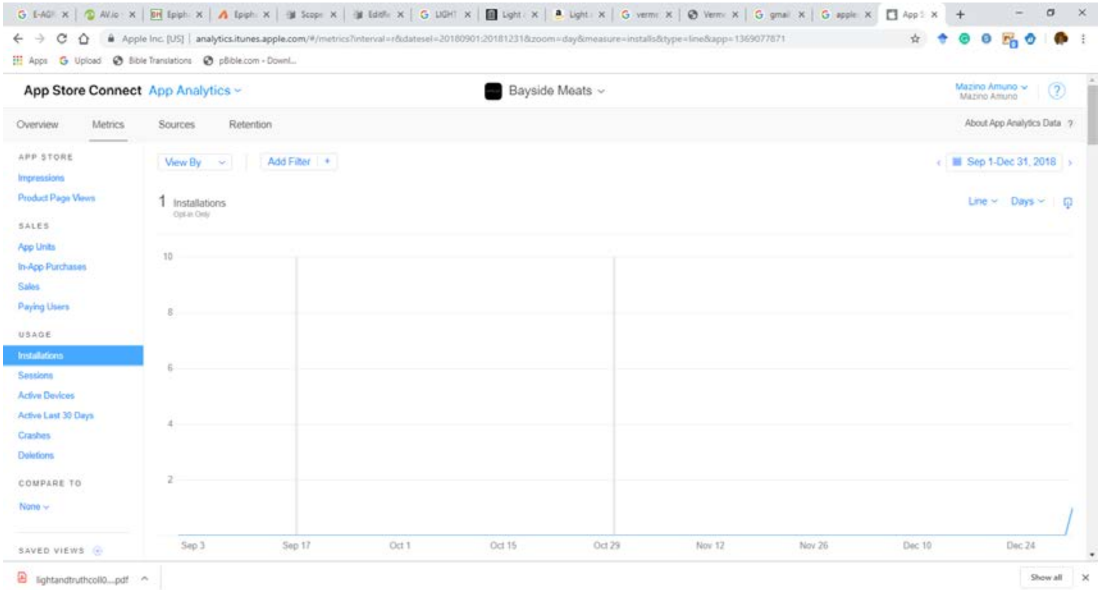
Description: Appendix Z shows the temperature monitoring system utilised by retail butcher 3 for monitoring the chilling condition of the cold store. The technology consist of an analogue sensor and analogue meter displays to show the temperature condition of the cold room.

APPENDIX Z1
MOBILE TECHNOLOGY INTERVENTION IN RETAIL BUTCHER 3 (CASE STUDY 4)

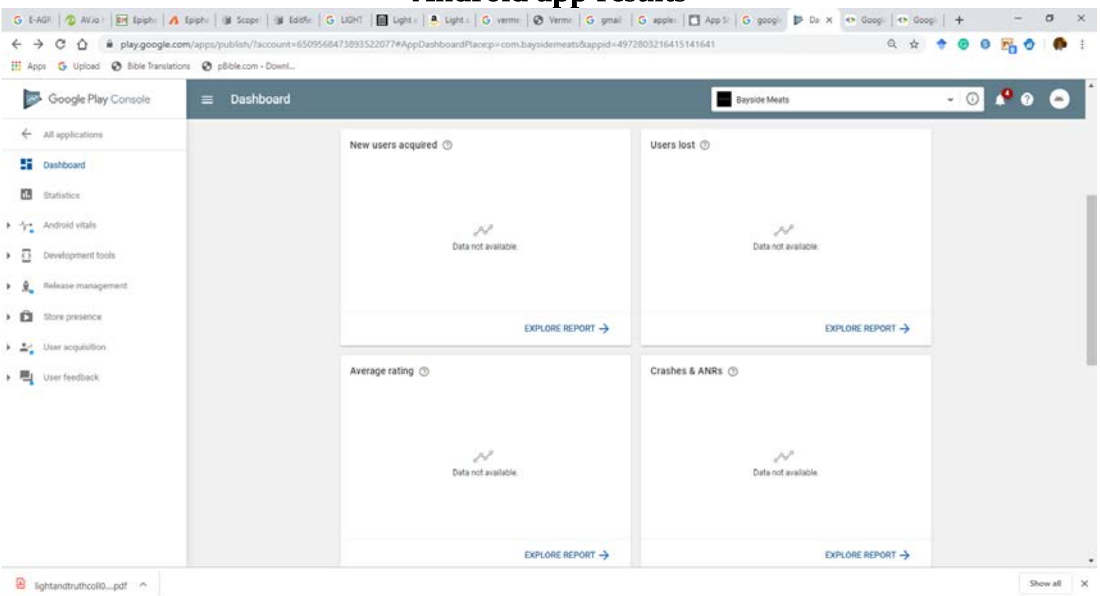


Description: The picture shown in this appendix is the mobile pp intervention deployed in retail butcher 3 (case study 4). The technology intervention consists of (a) an advertisement sheet displayed on the meat cabinet;(b) in-store QR code verification label that consumers that scan to learn more about their beef; and (c) and a QR code card that consumers can take to their homes and assess information on the beef purchased using their mobile devices. The intervention illustrates how low-cot mobile apps can be utilised by small retail meat butcher to enhance the value and quality of information aligned to traceability of meat. The intervention also illustrates an alternative approach using small QR code cards which consumers can collect from the store to access information on the origins of their meat at home through their mobile devices.

Appendix Z2:
iOS and Android app results



Android app results



Description: The figures shown in Appendix Z2 are the results of the consumer app download for both iOS and Android store in case study 4 (Butcher 3). As seen in both dashboards, no consumer downloaded the app in both app stores, suggesting a lack of consumer interest in the use of mobile verification app for supporting traceability of red meat.